İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

ANALYSIS OF EXPERIMENTAL DATA COLLECTED BY DRIVESAFE VEHICLE UYANIK

M.Sc. Thesis by
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Department : Mechatronics Enginerring

Programme : Mechatronics Engineering

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HAZİRAN 2011

Bitmesini Sabırla Bekleyen Sevgili Aileme,

FOREWORD

Automobile safety is a key concept in saving lives, preventing injuries and monetary damage. There are kinds of safety systems that work together or separately, to overcome different threats that may come from outside or within automobile. Majority of these systems are built in accordance with experience both real life and observation tests. In this thesis, observation test data are examined and analyzed coming from DriveSafe project, which was done aiming to gather raw material for this very purpose. As well as examining specific data, it is hoped to present and introduce this great supply of data for future projects and works.

First of all I would like to thank my supervisor Prof. Dr. Levent GÜVENÇ, for his great support and guidance, throughout my work. His creative and constructive ideas helped me to shape this project and achieving my master’s degree in science. Nonetheless I could not forget my friends at MEKAR Laboratory who assisted me in every time I needed. I also thank previous participants of DriveSafe project from whom I got information on unknowns of the project that took place five years ago.

Lastly, I commend my deepest respect to my beloved family that loved, believed in and supported me through my whole life.

May 2011

Kerem ÖZAÇMAK

Mechatronics Engineer

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ABBREVIATIONS

ABS	**:** Anti-lock Braking Systems
EBD	**:** Electronic Brakeforce Distribution
EBA	**:** Emergency Brake Assist
CBC	**:** Cornering Brake Control
TC	**:** Traction Control
ESC	**:** Electronic Stability Control
OTAM	**:** Otomotiv Araştırma Merkezi
ITU	**:** Istanbul Technical University
MEKAR	**:** Mekatronik Araştırma Laboratuvarları
HD	**:** High Definition
TB	**:** Tera Byte
GB	: Giga Byte
MB	**:** Mega Byte
GPS	**:** Global Positioning System
IMU	**:** Inertial Measurement Unit
DC	**:** Direct Current
AC	**:** Alternating Current
GUI	**:** Graphical User Interface
OSAS	**:** Obstructive Sleep Apnea Syndrome
EEG	**:** Electroencephalogram
NMEA	**:** National Marine Electronics Association
KML	**:** Kedit Macro Library
ECEF	**:** Earth Centered Earth Fixed
ENU	**:** East North Up
RTK	**:** Real Time Kinematic
UTC	**:** Universal Time Coordinated
HDOP	**:** Horizontal Dilution of Precision
DGPS	**:** Differential Global Positioning System
RTCM	**:** Real Time Correction Measure
DOF	**:** Degree of Freedom

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SUMMARY

This thesis is dedicated to one of most necessary and fundamental area in automobile industry; safety. Automobile safety has many branches within itself as a research area and it is not possible to express all of them in just one work, so several subjects were examined to give ideas about them.

There is one highlight of the thesis, coming from its major ancestor DriveSafe project. Secondary objective is to present and remind this huge project which could be further dug for potential academic works, thanks to its vast amount of real experimental data.

First step of this work is to accomplish this introductory burden to DriveSafe. After some background information about DriveSafe is given, like objective, test car and test subjects, more technical matters are brought to light as hardware and sensors installed on the car. Which sensor is responsible for gathering what kind of data is clearly told.

Later on, gathered data that was ready to be used in virtual environment was explained. This is done for each data type that is present in the folders.

Next step was to advance to analysis phase of data, where focused elements were GPS and test route. GPS data was converted from its raw format to be accessed in both geodetic and Cartesian graphs. To support results, visual aid was taken from GoogleEarth programme and they were found to be fitting in real life. Parallel to this chapter, experimental and simulation data were combined to form alternate versions of test route with data coming from IMU, CANBUS and double-track model of test car. By this way legitimacy of these methods were tested.

Slightly different analysis was made concerning identifying driver profiles with the help of four data types coming from CANBUS which were steering angle, vehicle speed, gas pedal percentage and brake pedal. For this analysis histogram technique was applied and results were satisfactory on being able to determine certain characteristics between 3 male and 3 female drivers.

Last of all results gotten from all analyses were discussed and connected in sense of underlining automobile safety.

GÜVENLİ SÜRÜŞ PROJE ARACI UYANIK İLE TOPLANAN VERİLERİN İNCELENMESİ

ÖZET

Bu tez çalışmasının konusu otomotiv endüstrisinin en temel ve gerekli alanı olan taşıt güvenliğine adanmıştır. Taşıt güvenliği, kendi içerisinde birçok dalı olan ve bütün bu dalların tek bir çalışmada anlatılamayacağı kadar büyük bir konudur, bu nedenle tez çalışmasında da fikir vermek adına belirli konulara değinilmiştir.

Tezin önemli bir özelliği ise kendisinden önce yapılmış, aynı amacı taşıyan ancak çok daha kapsamlı bir proje olan GüvenliSürüş projesiyle de yakından alakalı oluşudur. İkincil bir hedef olarak, GüvenliSürüş projesinin tanıtılması ve hatırlatılması öngörülmüş ve bu sayede gelecekteki projelerin de GüvenliSürüş deneylerinin sonucu olan devasa miktarlardaki deneysel verilerden yararlanmaları amaçlanmıştır. Bu kısımlar iyice anlatılıp hangi sensörün hangi veriyi kaydetmek için var olduğunun altı çizilmiştir.

Tezin ilk adımı olarak GüvenliSürüş projesinin tanıtılması yer almıştır. Proje amacı, test aracı ve denek sürücü adayları gibi arka plan bilgisi verdikten sonra daha teknik detaylar olan araçtaki test donanımı ve sensörlere geçilmiştir.

Bundan sonra ise sanal ortama kaydedilmiş deney verileri teker teker açıklanmıştır. Bu her veri cinsi için tekrar edilmiştir.

Sonraki adımda veri analizlerine geçilmiştir ve bu analizler sırasında odak noktası GPS verileri ve buna bağlı olarak şekillenen test rotası olmuştur. GPS verileri enlem/boylam ve Kartezyen grafiklerde kullanılmak üzere işlenmiştir. Bu grafiklere destek olarak GoogleEarth programı yardımıyla veriler gerçek uydu haritalarında çizdirilip sonuçların gerçek hayatta da örtüştüğü gözlenmiştir. Bu bölüme paralel olarak IMU, CANBUS ve çift izli taşıt modelinden gelen deneysel ve simülasyon verileri birlikte kullanılarak test rotasının varyasyonlarına ulaşılmış ve karşılaştırmalar yapılmıştır. Bu şekilde değişik metotların tutarlılığı ve gerçekliği anlaşılmıştır.

Sonraki bölümde biraz daha farklı bir sürüş analizi yapılmıştır. Bu bölüm yine CANBUS üzerinden gelen tekerlek açısı, araç hızı, gaz pedalı yüzdesi ve fren pedalı bilgilerinden sürücü profili çıkartmaya yöneliktir. Teknik olarak histogramlar kullanılmış ve 3 kadın 3 erkek sürücü arasında belirli sürüş karakteristikleri yakalanmaya çalışılmıştır.

Son bölümde ise bütün analizlerden toplanan sonuçlar genel bir değerlendirmeden geçirilmiş ve otomotiv güvenliği konusuna olan bağlantılar belirlenmiştir.

1. INTRODUCTION:

1.1 Background Information:

One of the biggest threats to human life comes from a very simple, yet very important aspect of everyday life, traffic. Especially in metropolises, thousands of vehicles and millions of pedestrians form a living traffic that never stops, even at late night or early in the morning. Naturally with this complexity and chaos, many complications and accidents occur, and they cost tremendous monetary damage and more importantly lives of people. Even though there are rules, drivers are human and they make mistakes. Avoiding driver behavioral mistakes is vital and car manufacturers constantly design active and passive safety systems to tolerate these mistakes and reduce the negative effects.

These safety systems take form from automobile design and equipments that are cleverly integrated to this design, to minimize the occurrence of accidents. Over the years, automobile safety systems have become more important and irrevocable, such that in many countries certain systems must be installed on cars by the law. These precautions work perfectly in real time conditions and practically caused accident casualties drop by a huge percentage.

In automobile industry there are two terms concerning safety; active and passive safety. Active safety refers to the technology that assists prevention of accidents, whereas passive safety is used for components or hardware of the car that protects people, in and out of the car, in case of an accident.

Active safety does its job before the accident, it is possible to state it as crash avoiding systems. Four major categories make up active safety in cars: head-backlights and reflectors, mirrors, brake, steering and suspension systems and driver assistance systems. Driver assistance systems are the most technological and developing area where electronics and control techniques are widely used. The most known assistance systems are;

-ABS (Anti-lock braking systems)

-EBD (Electronic brakeforce distribution systems)

-EBA (Emergency brake assist systems)

-CBC (Cornering Brake Control systems)

-TC (Traction control) systems which restore traction if driven wheels begin to spin

-ESC (Electronic Stability Control), which intervenes to avert an impending loss of control

-Automatic Braking systems to prevent or reduce the severity of collision.

-Infrared night vision systems to increase seeing distance beyond headlamp range

-Adaptive highbeam which automatically and continuously adapts the headlamp range to the distance of vehicles ahead or which are oncoming

-Adaptive headlamps swivels headlamps around corners

-Reverse backup sensors, which alert drivers to difficult-to-see objects in their path when reversing

-Backup camera

-Adaptive cruise control which maintains a safe distance from the vehicle in front

-Lane departure warning systems to alert the driver of an unintended departure from the intended lane of travel

-Tire pressure monitoring systems or Deflation Detection Systems

-Precrash system

-Automated parking system

Passive safety components are very common and take place in nearly all vehicles from their production phase. These components are seatbelts, airbags, laminated windshields, tempered glass windows, crumple zones that absorb energy, collapsible universally jointed steering columns and pedals. Some of this hardware also protects pedestrians during accidents, for example laminated windshields are designed to reduce injury as well as tempered glass, which crumple into little, harmless pieces instead of breaking into sharp fragments during an accident, and protects people both in and out of the car [1].

Even though there are these systems to protect people, accidents still do occur and take lives. Main reason is, no matter what safety system you put on a car and how advanced they are, people using them are not machines and they can do unexpected things with their nature. State of the driver has a tremendous effect on these accidents, like being drunk and tired. Today it is accepted that driving tired or sleepy is as dangerous as driving drunk. Tiredness, in fact, is more dangerous because it is hard to notice and may happen during driving periods, like in a long trip without giving breaks. Drivers in this state commonly find themselves in microsleeps which are extremely fatal. Crashes occur in periods less than a second and losing conscious even for that micro-period can lead to these crashes easily. Detecting this state of drivers' is very important to warn and stop them and prevent potential accidents.

1.2 Scope of Thesis:

In this thesis project, main goal is to go over different types of data coming from a real test car and analyze them for the sake of driving safety, search for clues to develop suitable systems that can act and save lives in emergency situations. It is also an introduction and summary of a bigger project done before it, hopefully first of many projects emerging from this ground-zero 'DriveSafe' project.

Drivesafe is a huge project, aiming this objective, done back in the year 2007 by the collaboration of several universities and companies such as Otomotiv Araştırma Merkezi (OTAM), Koç University, Istanbul Technical University, Sabanci University, Ford Otosan A.Ş., Renault Oyak A.Ş., and Tofaş A.Ş.. Scope of the project is pretty wide, ranging from building a fully operational test vehicle for data collection, a synchronized data recording and saving of the data coming from sensors and CANBUS data way, development of driver notification and aid systems, designing realistic car models and designing in-vehicle active safety systems.

In order to gather useful data and get an opinion of the general driving behavior, 108 candidates were chosen, of which 19 female and 89 male, from different age groups, and they were put to test on a route that consist of various road conditions of nearly 25 kilometers long. From narrow streets to highways, dense traffic to empty roads, sharp curves to flat roads, these candidates drove the test car in many situations for approximately 45 minutes. The car used in these tests was a 2006 model year Renault Megane II Sport Sedan 1.9 dCi in Figure 1.1, whose technical specifications are included in the appendix.

Figure 1.1: Test Vehicle 'Uyanık'

2. EXPERIMENTAL VEHICLE AND DATA COLLECTION:

2.1 Preparation and Setup:

Various data types were collected during these tests, which were collected by different sensors and devices positioned on the test car. There is one main desktop computer on the car for sensors to be connected and enable data flow, also a laptop computer from where the coming data are evaluated with specific softwares and programmes. Test car equipment can be seen in Figures 2.1-2.4.

Figure 2.1: Inside of the Car.

Figure 2.2: Flat Screen.

In the end, all together, a total of 700GB of data were collected from the experiments. HD videos taking the most space among them. These data were stored in several computers and external hard disks in case of emergency situations. Data types and sensors responsible for them are stated in the Table 2.1 below.

Figure 2.3: Main Desktop Computer.

Figure 2.4: Power Source in the Trunk.

Table 2.1: Data Types and Corresponding Hardwares [2].

Data Types Collected	**Hardware Used**
Vehicle Speed Angular Speeds of each wheel Engine RPM Steering Wheel Angle Steering Wheel Angular Speed Gear States (Neutral, Reverse, Drive) Gas/ Brake/Clutch pedal states Yaw Rate	Collected over the CANBUS network of the car with the help of an interface designed by İTÜ students.
Acceleration Measurement in 3-axes Angular Speed Measurement in 3-axes	XYZ accelerometer (IMU 400 Crossbow)
Vehicle position Latitude, Longitude, Altitude	GPS receiver (Trimble Pathfinder Pro XRS)
2 dimensional 180 degree scanning of the frontal area of the car (80 m ahead)	2D Laser scanner (LMS221-30206)
Back and Front Distance Data	Sonar sensors
Force and pressure measurement of brake pedal	Brake pedal pressure sensor
Analyzing voice of the driver for traces of tiredness	Microphones (Sony ECM-C115)
Fatigue Determination (Head/eye orientation, Eyelid movement/closure, gaze direction, lane following)	High resolution cameras (Basler A601 fc-2) Night vision camera (Basler A601 fc-HDR)

2.1.1 Accelerometer:

In order for accelerometer to work efficiently, it must be placed over and as closely as possible to the center of gravity of the car. It is simply a box and placed in the empty space between the front seats as seen in the picture. Required working voltage for accelerometer is between 9-25V DC, so feeding voltage is taken from the car’s lighter adapter which is 12V. Data cable is brought from between the front seats, to the process computer at the back seat and connected one of the serial ports as in Figure 2.5.

Figure 2.5: Accelerometer positioned at the bottom, between front seats.

2.1.2 GPS Receiver:

GPS receiver consists of two parts; antenna, which is Figure 2.6, and receiver module. Antenna is placed on the top of the car, and module to the shelf division at the left back seat. Working voltage of GPS receiver is between 10-32V DC. GPS adapter is connected and fed from the inverter in the car. Antenna is brought from the top of the car and connected to the module, which is similarly connected to the serial port of the process computer. Omnistar satellite is responsible for uplink and after some waiting period, it becomes available with a precision of nearly 40 centimeters.

Figure 2.6: GPS Antenna

2.1.3 Laser Scanner:

It is mounted on the front tip of the car, just over the bumper for best viewing position. A protecting structure is placed around it to reduce possible physical effects as in Figures 2.7 and 2.8. Laser scanner’s required 24V voltage is met with the help of a switched AC-DC converter. 220V AC input is taken from the inverter in the car. It is again connected to one of the serial ports of the vehicle computer. It has a range of approximately 80 meters in every individual 180 degrees ahead of the car.

Figure 2.7: Laser Scanner (Lidar)

Figure 2.8: Lidar Protection

2.1.4 Sonar Sensors:

There are 2 sensors each placed at front right, front left, rear right and rear left parts of the car, which are on the bumpers. They are adjusted to not to interact with each others' line of sight with an appropriate angle. Some sensors could be seen in Figures 2.9 and 2.10. Each sensor has 4 input-output ways that are; feed, ground, signal and echo. So 32 data cable are brought from front and back of the car to the back seat. In order for sonar sensors to work, a 5V DC voltage and square wave generator is required. Adjusting input-output of the sensors, feeding them with square wave and enabling a working voltage were done via a special circuit which was specially designed for this purpose. 32 data cables go into this circuit and sensor outputs are again taken over the circuit. Outputs are processed with a 24-channeled data collecting device called Alesis ADAT HD24 [3].

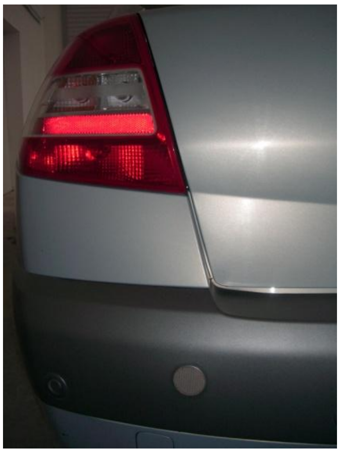


Figure 2.9: Sonar Sensors on the Rear Bumper

Figure 2.10: Close up View

2.1.5 Microphones:

At a certain point during the drive, test subjects are put on an extra challenge to examine their response to real life situations that can be experienced during driving. Subjects are asked to do a certain banking transaction while driving, communicating via a hands-free microphone. They talk with project members that act as bank employees, and transaction is purposely made a little difficult for them. Throughout this time, a microphone records their voices which can be analyzed for stress level, fluency and logic, that are associated with different patterns of driving forms.

2.1.6 Cameras:

Another type of data to be collected was in forms of images and sounds. Crash prevention systems should also keep track of driver's appearance and voice since human body gives certain clues about its fatigue level via these ways, which can lead to serious accidents. There are three HD-cameras on the car, two of them positioned in the car, viewing the driver from both directions with a slight angle. With these cameras it is possible to monitor all facial expressions and motions of the driver, especially eyes and head orientation. Many accidents happen due to a common situation among fatigued drivers called micro-sleep. Microsleep causes drivers to lose consciousness for a small period of time, yet very lethal in traffic and driving periods. Before microsleep, there are certain clues that can be spotted on driver's face, such as distorted head movements, closure of eyelids and disoriented looking directions. These data are collected for future use, focusing on preventing accidents due to fatigue by detecting them and warn drivers to be more careful. Also there is one camera mounted at the front of the car, viewing ahead, this camera is intended to be used in order to monitor lane following ability of the driver and warn if necessary, since lack of lane following is another sign of weariness. Below are screenshots from all 3 cameras in Figures 2.11-2.13.


Figure 2.11: Left Camera View **Figure 2.12:** Right Camera View

Figure 2.13: Front Camera View

2.1.7 Alesis ADAT HD24:

ADAT stands for Alesis Digital Audio Tape, which is a tape format for recording different numbers of digital audio tracks onto magnetic tapes or hard disks. From the first time it was introduced in 90’s, Alesis products were favored for their control and adjustment ability on recorded audio samples and relatively low cost. As years passed, recording type changed from tape-based to disk-based, though tape-based formats can still be found. [4] Alesis ADAT HD24 is the last successor among stand alone digital multitrack recorders, meanwhile it is world’s first 24-channel hard disk recorder. It is exclusively built for recording music instead of data, but in DriveSafe project, it is used in both fields. Optionally with a small upgrade called EC2 module integrated, HD24 signal quality may be enhanced by sacrificing half of signal number. Of course HD24 true potential and capabilities lies for audio usage like cut, copy, paste, synchronization between different audio tracks can be easily done [5]. Back and front sides of the device can be seen in Figure 2.14.

Figure 2.14: Front and Back View of Alesis ADAT HD24 [6].

2.2 Data in Detail:

DriveSafe was a huge project, where nearly every bit of data that could be related to automobiles and driving, were collected and kept. For this reason it was a future-proof project, since many types of data may be used in various projects in the future. Even at this point, only a certain portion of data is used and analyzed, some data types were never even touched.

All data collected during experiments were stored in several computers and a 1TB external hard disk. They cover a total of nearly 700 GB of space, most of which are HD videos. Every driver has its own set of data in separate folders which are identified with certain names. The names are in ‘I(F/M)10XX’ format where ‘F’ or ‘M’ represents gender (female/male) and ‘XX’ defines the number of the driver. ‘I’ letter and ‘10’ digits remain same for all driver codes. As mentioned before there are 108 drivers, of which 19 female and 89 male, though 2 female and 1 male driver’ data are lost, which reduces total number down to 105.

When a driver’s folder is opened, there are 5 more sub-folders with different kinds of data. Roughly they can be grouped in three different categories as; video, audio and numeric. There are 2 folders for video and audio categories each, and one folder for the numeric data. Sub-folders are distinguished by additional letters added at the end of driver ids, for example for video sub-folders there are ‘V’ and ‘VA’ adds, which correspond to ‘video’ and ‘video with audio’. Similarly for audio sub-folders, the add-ons are ‘A’ and ‘AS’, which represents ‘audio’ and ‘audio stereo’. For numeric data there is only one folder that goes with ‘M’ added at the end. This is the standard format of a data set, for some drivers, data sets lack certain parts of this standard format due to various complications. Sub-folders of a random driver are shown in Figure 2.15.

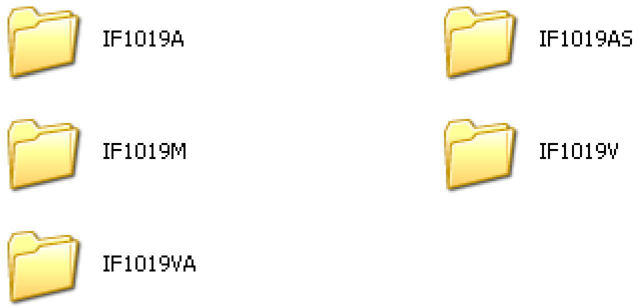


Figure 2.15: Sub-folders of a Data Set

2.2.1 Video Data:

Video data consist of three ‘.avi’ extensional files, two of which show drivers during the test drive from left and right directions. Camera is focused on driver’s face and there is not much background. Other avi file is the recording of the drive, viewing from the front bumper level of the car and looking ahead. Each file is approximately 1 GB for non-audio types, audio adds 100 MB to the videos which makes them the largest set of data gathered during DriveSafe project. These files can be opened and run with any media player.

2.2.2 Audio Data:

There are 4 microphones positioned at certain locations inside the car. These microphones receive sound waves from different perspectives. Main objective for microphones is to record the driver’s voice during his or her interaction over the phone while driving. This interaction may be in several forms like making a bank transaction, reading vehicle license plates or paying attention to something while driving. One of the audio files is the record of this interaction from asker’s side, so it is possible to hear questions and answers both. There are two folders for audio files, mono and stereo, in mono folder marked with ‘A’ there are five files in sound wave format and in stereo folder marked with ‘AS’ there are 3, which are stereo versions of the files in mono folder. They are all each 90 MB and that makes them the second largest data kind in the project.

2.2.3 Numeric Data:

Numeric data folder contains 4 files which are most important and detailed data for the project. All the information coming from the installed sensors and the car itself are saved within these files. Today almost every car has its own mini-computer called ECU, where all information about the car is electronically saved and analyzed throughout its journeys. ECU has a port that can be connected to via a simple laptop, called CANBUS port, and all the data can be downloaded from the car. This ‘.can’ file is one of the data type in numeric data folder. What it contains is as follows; steering wheel angle, steering wheel radial speed, vehicle speed, wheel speed front right, wheel speed front left, wheel speed rear right, wheel speed rear left, percent gas pedal, engine rpm, neutral (gear) state, yaw rate, clutch state, reverse gear, brake (pedal) state, clutch maximum (state) and time, which are in Figure 2.16.

SWA	SWRS	VS	WSFR	WSFL	WSRR	WSRL	PGP	ERPM	NS	YR	CS	RG	BS	CM	timeFri Dec 15 14:52:24 2006
-21.200	0.300	1.180	1.115	1.086	1.115	1.052	12.500	829.000	1	0.000	1	0	1	1	1587.047 Fri Dec 15 15:18:52 2006
-21.100	0.000	0.950	0.965	0.874	0.903	0.874	12.500	822.000	1	0.000	1	0	1	1	1587.156 Fri Dec 15 15:18:52 2006
-21.200	0.000	0.780	0.753	0.782	0.753	0.724	12.500	817.000	1	0.000	1	0	1	1	1587.266 Fri Dec 15 15:18:52 2006
-21.200	0.000	0.670	0.724	0.661	0.661	0.661	12.500	811.000	1	0.000	1	0	1	1	1587.375 Fri Dec 15 15:18:52 2006
-21.200	0.000	0.670	0.661	0.632	0.603	0.632	12.500	807.000	1	0.000	1	0	1	1	1587.484 Fri Dec 15 15:18:52 2006
-21.300	0.000	0.610	0.603	0.603	0.603	0.603	12.500	799.000	1	0.000	1	0	1	1	1587.594 Fri Dec 15 15:18:52 2006
-21.300	0.000	0.610	0.603	0.603	0.570	0.570	12.500	799.000	1	0.000	1	0	1	0	1587.703 Fri Dec 15 15:18:52 2006
-21.300	0.000	0.610	0.570	0.570	0.570	0.570	12.946	778.000	1	0.000	1	0	1	0	1587.813 Fri Dec 15 15:18:52 2006
-21.300	0.000	0.560	0.541	0.541	0.541	0.541	12.500	808.000	1	0.000	1	0	1	0	1587.922 Fri Dec 15 15:18:53 2006
-21.300	0.000	0.560	0.541	0.512	0.541	0.541	12.500	787.000	1	0.000	0	0	1	0	1588.031 Fri Dec 15 15:18:53 2006
-21.300	0.000	0.560	0.512	0.512	0.541	0.512	12.500	803.000	1	0.000	0	0	1	0	1588.141 Fri Dec 15 15:18:53 2006
-21.300	-0.400	0.560	0.512	0.512	0.483	0.512	12.500	810.000	1	0.000	0	0	1	0	1588.250 Fri Dec 15 15:18:53 2006
-3.600	-9.200	56.300	55.538	55.418	55.659	55.659	12.500	824.000	1	0.000	1	0	1	1	2530.375 Fri Dec 15 15:34:35 2006
-4.200	-0.400	56.020	55.476	55.147	55.418	55.205	12.500	826.000	1	0.000	1	0	1	1	2530.484 Fri Dec 15 15:34:35 2006
-4.200	0.300	55.400	54.872	54.481	54.843	54.723	12.500	833.000	1	0.400	1	0	1	1	2530.594 Fri Dec 15 15:34:35 2006
-4.100	1.000	54.900	54.361	54.148	54.332	54.090	12.500	837.000	1	0.200	1	0	1	1	2530.703 Fri Dec 15 15:34:35 2006
-3.700	4.900	54.330	53.516	53.545	53.786	53.516	12.500	839.000	1	0.400	1	0	1	1	2530.813 Fri Dec 15 15:34:35 2006
-3.200	0.700	53.600	52.883	52.941	53.217	53.246	12.500	846.000	1	0.000	1	0	1	1	2530.922 Fri Dec 15 15:34:36 2006
-3.200	0.700	53.100	52.521	52.401	52.671	52.671	12.500	842.000	1	0.000	1	0	1	1	2531.031 Fri Dec 15 15:34:36 2006
-3.200	-0.400	52.700	51.797	51.855	51.889	51.889	12.500	842.000	1	0.000	1	0	1	1	2531.141 Fri Dec 15 15:34:36 2006
-3.200	2.100	52.030	51.315	51.286	51.373	51.315	12.500	837.000	1	0.200	1	0	1	1	2531.250 Fri Dec 15 15:34:36 2006
-2.900	0.000	51.300	50.740	50.711	50.682	50.682	12.500	846.000	1	0.000	1	0	1	1	2531.359 Fri Dec 15 15:34:36 2006
-3.900	-17.600	50.730	50.108	50.200	50.407	50.229	12.500	837.000	1	0.000	1	0	1	1	2531.469 Fri Dec 15 15:34:36 2006
-7.400	-45.000	50.680	50.108	50.137	50.079	50.137	12.500	839.000	1	0.000	1	0	1	1	2531.578 Fri Dec 15 15:34:36 2006
-13.300	-58.100	50.620	49.987	49.804	49.925	49.838	12.500	835.000	1	0.400	1	0	1	1	2531.688 Fri Dec 15 15:34:36 2006
-19.600	-51.000	50.400	49.958	49.534	49.958	49.534	12.500	850.000	1	2.000	1	0	1	1	2531.797 Fri Dec 15 15:34:36 2006
-24.600	-41.200	50.230	49.838	49.476	49.838	49.413	12.500	843.000	1	3.400	1	0	1	1	2531.906 Fri Dec 15 15:34:36 2006
-29.000	-38.700	50.060	49.625	49.051	49.775	49.143	12.500	848.000	1	5.000	1	0	1	1	2532.016 Fri Dec 15 15:34:37 2006
-32.800	-29.200	49.830	49.534	48.872	49.563	48.993	12.500	839.000	1	5.200	1	0	1	1	2532.125 Fri Dec 15 15:34:37 2006
-34.400	0.000	49.550	49.476	48.539	49.413	48.781	12.500	845.000	1	6.200	1	0	1	1	2532.234 Fri Dec 15 15:34:37 2006

Figure 2.16: M1 File (CANBUS) Contents

Steering wheel angle is in degrees, whereas steering wheel radial speed is in radians per second, and they are the most characteristic data that can be used to distinguish between different drivers and their driving patterns or habits. Vehicle and wheel speeds are in kilometers per hour just as the values in car tachometers, so is the engine rpm. Percent gas pedal shows how much the pedal is pressed and proportional to engine rpm. Yaw rate measures from the lateral forces acting on the car, and is degrees per second. Gear states and brake values are in 1 or 0 format, representing 1 as positive and 0 as negative.

Second file in numeric folder comes with the name M2 and contains the GPS information of the journey during test drive like in Figure 2.17. One thing to note is all GPS data files begin with thousands of undefined data rows, which indicates to time interval when GPS unit is trying to achieve necessary number of satellites to start with. After that meaningful values take place on the spreadsheet. Values are pretty clear in the order; UTC time, latitude, longitude, quality indicator, satellite number, horizontal dilution of precision, altitude, geoidal height and the time since last GPS update. Most important values here are the latitude, longitude and altitude which were used in GPS Analysis section where M2 files were examined closely.

GPStime	Latitude(N)	Longitude(W)	FixQual	NUMofSA	HDOP	Altitude	Wgs84	Milisecon	timeWed Aug 08 10:32:36 2007
07.52.47	4.106.553.050	29.018.942	1	7	01.Ağu	130.48	39.48	1589.250	Wed Aug 08 10:59:06 2007
07.52.47	4.106.552.115	29.018.892	1	7	01.Ağu	130.48	39.48	1589.281	Wed Aug 08 10:59:06 2007
07.52.48	4.106.552.115	29.018.892	1	7	01.Ağu	130.69	39.48	1590.250	Wed Aug 08 10:59:07 2007
07.52.48	4.106.551.342	29.018.842	1	7	01.Ağu	130.69	39.48	1590.281	Wed Aug 08 10:59:07 2007
07.52.49	4.106.551.342	29.018.849	1	7	01.Ağu	130.84	39.48	1591.250	Wed Aug 08 10:59:08 2007
07.52.49	4.106.550.664	29.018.819	1	7	01.Ağu	130.84	39.48	1591.281	Wed Aug 08 10:59:08 2007
07.52.50	4.106.550.664	29.018.810	1	7	01.Ağu	130.99	39.48	1592.250	Wed Aug 08 10:59:09 2007
07.52.50	4.106.550.141	29.018.770	1	7	01.Ağu	130.99	39.48	1592.281	Wed Aug 08 10:59:09 2007
07.52.51	4.106.540.141	29.018.779	1	7	01.Ağu	131.14	39.48	1593.250	Wed Aug 08 10:59:10 2007
07.52.51	4.106.549.758	29.018.759	1	7	01.Ağu	131.14	39.48	1593.281	Wed Aug 08 10:59:10 2007
07.52.52	4.106.549.758	29.018.754	1	7	01.Ağu	131.29	39.48	1594.250	Wed Aug 08 10:59:11 2007
07.52.52	4.106.549.458	29.018.734	1	7	01.Ağu	131.29	39.48	1594.281	Wed Aug 08 10:59:11 2007
07.52.53	4.106.549.458	29.018.735	1	7	01.Ağu	131.36	39.48	1595.250	Wed Aug 08 10:59:12 2007
07.52.53	4.106.549.223	29.018.715	1	7	01.Ağu	131.36	39.48	1595.281	Wed Aug 08 10:59:12 2007
07.52.54	4.106.549.223	29.018.714	1	7	01.Ağu	131.44	39.48	1596.250	Wed Aug 08 10:59:13 2007
07.52.54	4.106.548.890	29.018.684	1	7	01.Ağu	131.44	39.48	1596.281	Wed Aug 08 10:59:13 2007
07.52.55	4.106.548.890	29.018.688	1	7	01.Ağu	131.46	39.48	1597.250	Wed Aug 08 10:59:14 2007
07.52.55	4.106.548.357	29.018.688	1	7	01.Ağu	131.46	39.48	1597.281	Wed Aug 08 10:59:14 2007
07.52.56	4.106.547.801	29.018.656	1	7	01.Ağu	131.50	39.48	1598.281	Wed Aug 08 10:59:15 2007
07.52.57	4.106.547.801	29.018.625	1	7	01.Ağu	131.68	39.48	1599.250	Wed Aug 08 10:59:16 2007
07.52.57	4.106.547.321	29.018.595	1	7	01.Ağu	131.68	39.48	1599.281	Wed Aug 08 10:59:16 2007
07.52.58	4.106.546.863	29.018.578	1	7	01.Ağu	131.79	39.48	1600.281	Wed Aug 08 10:59:17 2007
07.52.59	4.106.546.863	29.018.574	1	7	01.Ağu	131.90	39.48	1601.250	Wed Aug 08 10:59:18 2007
07.52.59	4.106.546.486	29.018.554	1	7	01.Ağu	131.90	39.48	1601.281	Wed Aug 08 10:59:18 2007

Figure 2.17: M2 File (GPS) Contents

In the third file named as M3, data coming from IMU sensor take place. Roll-pitch-yaw rates which are in degrees per second and X-Y-Z accelerations in g's, are the highlights in these files that can be spotted from Figure 2.18. Also there is the temperature sensor in Celsius and timer part that is along with that data. Especially yaw and roll rates were important for DriveSafe project, since while taking corners with a car, accidents occur, either by spinning out due to huge yaw rates or roll over because fast displacement of center of gravity of the car due to roll rate. Certain algorithms and control methods were created to overcome these dangerous situations in DriveSafe project.

Time (s)	Roll rate (deg/s)	Pitch rate (deg/s)	Yaw rate (deg/s)	X Accel (g)	Y Accel (g)	Z Accel (g)	Temperature (°C)	Timer counts
764,46228	0,192261	-0,073242	0,942993	0,026367	-0,017761	0,949219	46,821	30380
764,507324	-0,567627	0,732422	0,3479	-0,013916	-0,023071	1,021362	46,875	39186
764,604919	-0,100708	-0,201416	0,723267	0,021973	-0,004761	1,001953	46,821	47308
764,702393	0,201416	-0,476074	-0,109863	0,008606	-0,01355	1,0177	46,875	55512
764,807434	-0,292969	0,952148	0,723267	-0,011169	-0,020325	1,018982	46,875	54252
764,904907	-0,064087	0,137329	0,219727	0,026917	-0,001282	1,0047	46,712	62452
765,002502	0,265503	0,146484	-0,054932	0,003479	-0,019226	1,030701	46,766	5111
765,100037	0,320435	1,107788	-0,238037	0,028931	-0,034058	0,964966	46,875	13251
765,205078	0,256348	0,640869	0,50354	0,02417	-0,004211	1,006531	46,875	11871
765,302673	-0,009155	0,888062	-0,402832	-0,002563	-0,026367	1,033081	46,766	20026
765,400208	0,009155	0,292969	0,778198	0,02179	-0,027832	0,966064	46,766	28164
765,50531	0,045776	0,073242	0,411987	0,024719	-0,006409	1,010376	46,875	26879
765,602844	1,062012	0,32959	0,219727	0,007324	-0,021423	1,027405	46,821	34960
765,700378	-0,439453	0,421143	0,064087	0,023987	-0,028931	0,966064	46,821	43165
765,80542	0,686646	0,521851	0	0,023071	-0,00531	1,007629	46,821	41871
765,902893	0,723267	0,640869	0,247192	0,008972	-0,020325	1,026672	46,821	50103
766,000488	0,137329	0,137329	0,842285	0,028381	-0,030579	0,966614	46,821	58244
766,10553	0,723267	0	-0,897217	0,022522	-0,007507	1,005981	46,821	56954
766,203064	-0,109863	0,695801	1,071167	0,011902	-0,016479	1,021179	46,875	65153
766,300537	0,128174	0,704956	0,595093	0,027832	-0,029663	0,971008	46,875	7788
766,405579	-0,064087	-0,128174	-0,650024	0,025818	-0,005859	1,0047	46,875	6510
766,503113	0,814819	0,485229	0,50354	0,010803	-0,017029	1,023926	46,875	14691
766,600647	1,556396	-0,439453	0,814819	0,025085	-0,030762	0,968811	46,821	22876
766,705688	0,933838	0,613403	0,686646	0,023071	-0,006958	1,004883	46,766	21586

Figure 2.18: M3 File (IMU/Accelerometer) Contents

Laser sensor data is stored in M4 files and shown in Figure 2.19, that are needed to detect what obstacles are ahead of the car, which can be very lethal in case of emergency situations. Laser scanner has its own software where, graphically, front area of the car is shown and other cars or pedestrians can be spotted. Refresh rate of the device is 1-2 Hz, which, in every cycle scans 180 degrees and returns the radius information at each individual degree, so this way obstacles can be known. Data file consists of five columns, where first column stands for a general number list, second column the radii of the frontal area, third column relevant degree values to those radii and fourth and fifth columns are the X and Y coordinates of those points respectively.

```
All measured values of a scan are formatted.;Tuesday, 14.August 2007 - 10.53.13;
No.;Radius;Angle; X-value; Y-value;Status
  1; 1980cm;  0.00°; 1980cm;    0cm;
  2; 2351cm;  1.00°; 2351cm;   41cm;
  3; 2364cm;  2.00°; 2363cm;   83cm;
  4; 2381cm;  3.00°; 2378cm;  125cm;
  5; 2398cm;  4.00°; 2392cm;  167cm;
  6; 2412cm;  5.00°; 2403cm;  210cm;
  7; 2429cm;  6.00°; 2416cm;  254cm;
  8; 2448cm;  7.00°; 2430cm;  298cm;
  9; 2478cm;  8.00°; 2454cm;  345cm;
 10; 2492cm;  9.00°; 2461cm;  390cm;
 11; 2497cm; 10.00°; 2459cm;  434cm;
 12; 1428cm; 11.00°; 1402cm;  272cm;
 13; 2525cm; 12.00°; 2470cm;  525cm;
 14; 2547cm; 13.00°; 2482cm;  573cm;
 15; 2557cm; 14.00°; 2481cm;  619cm;
 16; 2577cm; 15.00°; 2489cm;  667cm;
 17; 2592cm; 16.00°; 2492cm;  714cm;
 18; 2613cm; 17.00°; 2499cm;  764cm;
 19; 2640cm; 18.00°; 2511cm;  816cm;
 20; 2176cm; 19.00°; 2057cm;  708cm;
```

Figure 2.19: M4 File (Laser Scanner/Lidar) Contents

2.3 Programmes Used For Data Examination:

In the gathering phase of the experiment, accelerometer, laser and GPS sensors had their own softwares that enabled these particular data to be collected and stored separately. It was very helpful since different data had different units and formats, with their own softwares data was clearly and neatly listed.

In order to accomplish the DriveSafe projects main objective, nearly all data types must be simultaneously observed and analyzed, this also includes video and audio data. Manufacturer softwares that were used to extract sensor data are not suitable for this purpose, so there is a new need for a software which can do the job.

This is a big programming project and requires serious computer engineering skills. In 2006, when DriveSafe was at its first year, a group of students designed a programme that was supposed to monitor all data types and simulate them as synchronized in real time. It was called DriveSafeGUI and had a plug-in basis backbone where there was a specific plug-in for each data type. In the menu of the programme, user could open each data type that needs to be presented and select among them, including video and audio files, like in Figure 2.20 and 2.21.

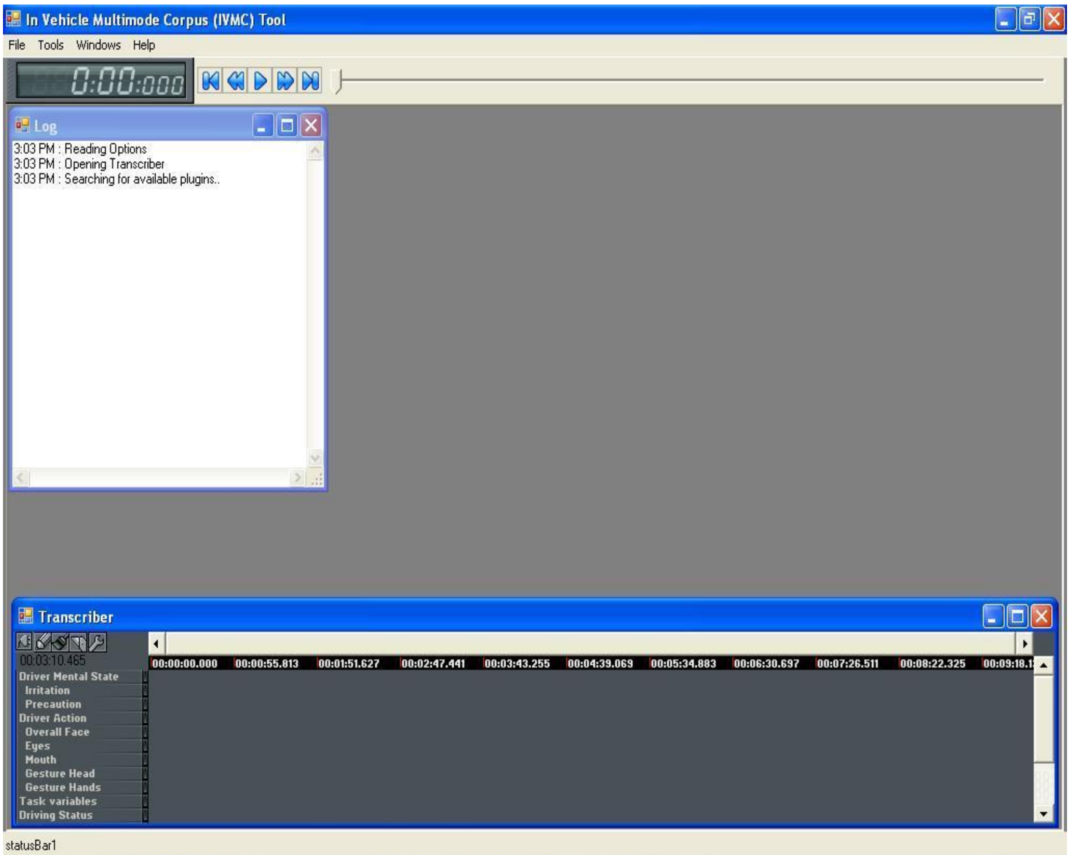


Figure 2.20: Workspace of DriveSafeGUI Programme

In every data file there is a time column which is crucial for data to be viewed at correct times, also in the programme menu, after data are imported and ready to be analyzed, time can be tracked and adjusted with the help of a time bar above. At a specific point, for example at high speeds, driver's face could be examined for lack of attention by stopping the simulation, or viewing from front camera, vehicle dynamics could be studied over a hard turn for a small period of time.

For every data type, there opens a graphical interface for users to observe. Due to some plug-in problems, for now, only video, audio and CANBUS files are usable. Video files can be watched together in windows, from all three cameras with or without audio. CANBUS window shows all data in column format which is easy to comprehend, which can be seen in Figure 2.22.

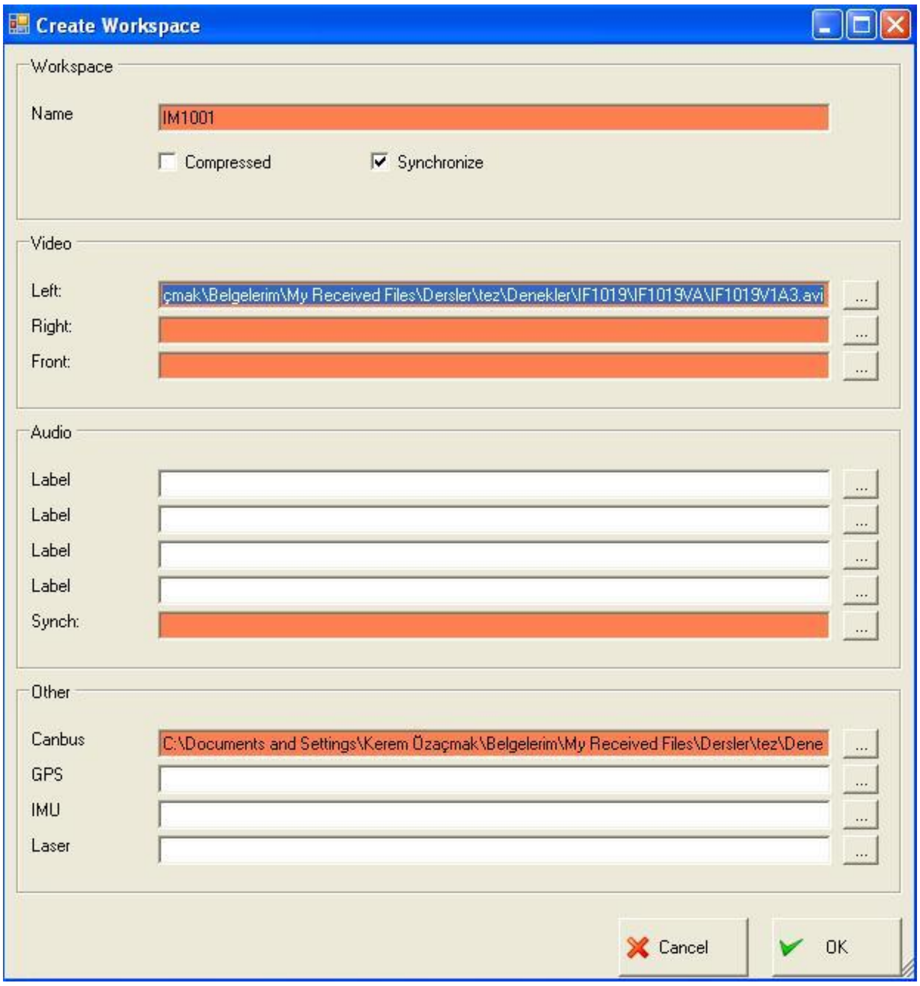


Figure 2.21: Input Insertion to the Programme

Unfortunately there is a problem with time synchronization among data types that designer group could not overcome. There are a few versions of the programme that differ slightly according to their plug-ins but none of them are able to run video and

CANBUS data synchronized. The best version runs CANBUS with no mistakes but video data is always lagged and delayed.

Figure 2.22: CANBUS View of the Programme

There is a simple, yet not practical solution to this problem which is basically opening video and CANBUS files in different programme versions in which they work properly. By this method they are able to run simultaneously, but there is the problem of synchronization again. You have to adjust time bars and start them from the same point and end at same points to gather useful data like in Figure 2.23.

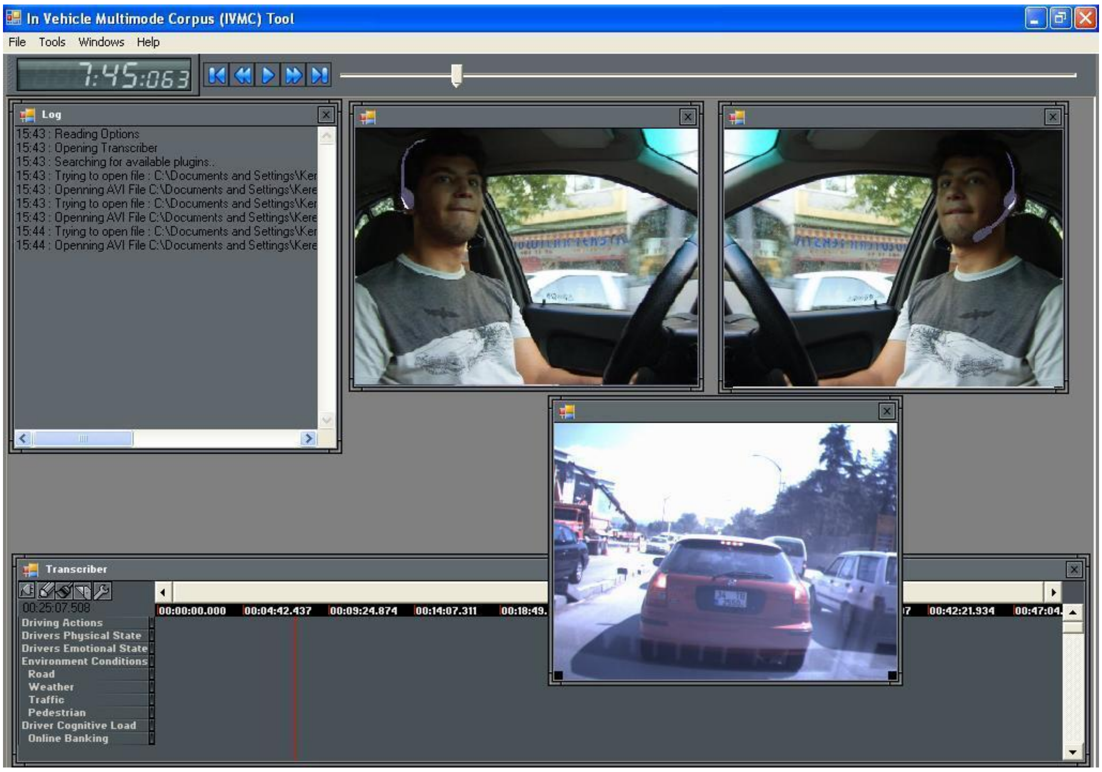


Figure 2.23: Video Files Running

It is possible to write small codes or routines to overcome this problem, but to have a flawless and healthy interface, further work must be done by computer engineers. If all data types can be monitored synchronizingly and simultaneously, it will be very promising for the future of the project.

2.4 Literature Review:

There are numerous works throughout the world concerning vehicle and passenger safety, and they will surely increase as car industry and demand rises with population. Developing new safety systems, improving auto designs and conducting statistical researches on people's driving profiles are different areas of these ongoing works. Even with a quickly done survey, many examples may be found.

Most related article, other than this thesis, to DriveSafe is the first report done after the experiments were conducted and finished [7]. It was a general report, at the same time a presentation of DriveSafe, though there were also some vehicle safety systems introduced like collision preventing, yaw and roll stability systems. These systems were designed based on the data coming from DriveSafe and was supported by the simulators in MEKAR Lab to assist designs. Also double-track vehicle model of the test car 'Uyanık' was created in need of this project.

However not every journal is about technical subjects, there are also some statistical researches that give important clues about reasons why accidents occur. In England and Sweden, bus drivers' driving performance was closely watched who took long breaks from work for various health issues [8]. It is seen that there is a correlation between crash number and time spent away from work. It is understandable why transportation companies must keep track of their personnel and their moral condition.

Another related paper is done on people who suffer from obstructive sleep apnea syndrome (OSAS), but at the same time have licenses [9]. This sickness drains people sleep time and leaves them in a drowsy state. In the project 12 men, 12 women, 24 test subjects diagnosed with OSAS, were participated in an hour long test drive to identify microsleep periods with EEG. Results indicate deterioration in driving performance during microsleep periods, especially on curved roads. So identifying these periods and taking countermeasures is essential for the sake of people.

A very similar project to DriveSafe, where the objective is to detect and classify driving profiles, is done via using only computer vision [10]. Main difference is the fundamental use of computer image processing algorithms to group driver activities as safe or unsafe to take necessary precautions. Since there are massive video and audio data collected from DriveSafe and they remain untouched, this project could prove inspiring to start a project concerning their use. Another activity classification technique is used, based on the idea from black boxes in airplanes [11]. Black boxes can be used to gather information in case of a traffic accident, as well as normal driving. Again for this project, gathered data is analyzed for forming a dangerous driving cognition system. This is done with the aid of an algorithm that divides dangerous driving profiles into 4 categories, according to acceleration, deceleration, turning and number of traffic accident and this algorithm is embedded in the black box.

3. GPS ANALYSES:

3.1 What is GPS:

Global Positioning System, commonly referred as GPS, is a long range radio frequency global network, which is bonded with 24 geosynchronous satellites which have their own unique orbits around the Earth. Information flowing through these satellites can be received by special devices called GPS units to determine precise location of this unit or the construction that it is attached to, during a specified time interval of the signals transmission. In a GPS unit, the most important part is GPS module, which is responsible for signal receiving and calculation of the coordinates. Later on, this information can be projected onto a map, where it represents the location with respect to a scale, either in real time or can be stored in memory for later analyses [12].

There are mainly 3 types of GPS units currently in use; data loggers, data pushers and data pullers. Data loggers is the most basic one, it simply logs the position during a certain time interval and stores its information in its internal memory. Memory can be in forms of flash drives or memory cards which make it easy to access this stored information with computers or similar hardware.

Data pushers are the most commonly used GPS units and are favored in both personal and vehicle tracking systems. ‘Push’ phrase is used to mean that these devices can send gathered data to a main server, which is in most cases different GPS manufacturers’ servers. Data can also be stored and analyzed within these servers as well as the GPS unit itself. Today one of the popular systems for cars is the automatic vehicle location system, where the GPS beacon is installed on the car, also connected to the CANBUS data way of the car and the battery for power. This system can track cars of companies or individuals and their data can be accessed over the internet for controlling and checking in case of a problem or emergency situation. Similarly navigation systems on cars use the same principle and these devices can send other information like speed or altitude as well as coordinates of locations.

Data pullers are slowly coming into daily life and they are capable of everything a data pusher can do. What it does additionally is, to respond to the calls or messages sent to it. For example if the device is on a yacht that does world travel, with a simple SMS, current location of the yacht at that moment comes to the cell phone where the SMS was sent [13].

There are many kinds of GPS data formats suitable for various applications. Among them, two specific formats are highlighted for this project; NMEA 0183 and KML. NMEA 0183 (National Marine Electronics Association) is a language developed for GPS, sonar and radio communications [14]. GPS unit used in DriveSafe project uses this language and outputs accordingly. There is a newer version of NMEA called NMEA 2000, which is further advanced and able to combine with CANBUS data ways of vehicles, although it is unfortunately not supported by Pathfinder Pro XRS.

Other format used was named KML and is designed by a sub-company owned by Google to integrate GPS data to 2D maps, which is naturally Google Earth. Conversions to this format was done in order achieve enhanced visuality and clarity for the routes that were drawn.

3.2 Calculations and Analysis:

One of the data types gathered from experiments was GPS coordinates of the test vehicle during its course. GPS is one of the most precise methods of determining displacement route of mobile units and is used by nearly all kinds of vehicles like cars, trucks, ships and airplanes. GPS device used was Trimble Pathfinder Pro XRS which consisted of a receiver and an antenna, mounted on top side of test vehicle. It works between 10 to 32 VDC and with a maximum power of 7 Watts. Official update rate of the device is 1 Hz but from the data collected, slightly higher and lower values are also noted. GPS data is secured to files with the help of Trimble's own software which comes with the device. Some configurations can be done about the output format of the device such as data transfer speed and numeric representations. Configuration parameters are adjusted with the help of NMAE code formats which are included in the appendix. There are many GPS numeric representations and among them, Trimble Pathfinder Pro XRS uses NMEA 0183 format. Along with latitude and longitude, comes some more additional information listed in Table 3.1 on the next page:

Table 3.1: GPS Data in Detail [15]

Time	UTC of Position (hhmmss.ss)
Latitude	Latitude of Position (ddmm.mmmmmm) N or S letters determine latitude hemisphere
Longitude	Longitude of Position (ddmm.mmmm), E or W letters determine longitude hemisphere
Fix Quality:	GPS Quality Indicator - 0 = Invalid - 1 = GPS fix - 2 = DGPS fix - 6 = Estimated fix
Number of Satellites	Number of Satellites In Use
Horizontal Dilution of Precision (HDOP)	Horizontal Dilution of Precision
Altitude	Antenna Altitude Above Mean-Sea-Level (meters)
Height of geoid above WGS84 ellipsoid	Geoidal height (meters)
Time since last DGPS update	Age of Differential GPS data (milliseconds since last valid RTCM transmission)

GPS data points differ in number for each driver, even though they all have completed very similar circuits. The reason is mainly the working frequency of the device, it is proportional to data points collected. For lower frequencies the number of data is low as well, and if higher, mostly up to 2 Hz, there are more data points. Throughout the drivers, low frequency data are noted to be around 1000-1500 points whereas higher frequencies range from 3500-7000. There are 15 drivers whose GPS data are corrupt or not recorded due to technical problems and 16 drivers whose data lack desired pattern, so there are total of 74 pieces of data taken into account. List of drivers with related GPS points is in the appendix.

First step of analyses was to enhance the visualization, plot or draw the test circuit where the test car was being used. GPS data that was in ‘degree/minutes’ format was converted to ‘decimal-degrees’ format to overcome the gap problems in plots. Since plot axes are in decimal format and GPS points are in sexagesimal format due to minute values, if coordinates are plotted without being converted, then plot contains some false patterns that spoil the visuality of the circuit. Converting process was simple, since minutes were already in decimal format, only thing to do was divide minutes by 60 (60 minutes = 1 degree) and add to the degrees.

Original GPS data are stored in ‘Headerless RAW Waveform’ files created by Trimble Software, which can be opened by Notepad or Excel to view its contents. Converting process is done in Excel since the four arithmetical operations for columns can be easily done, and Excel files are capable of being imported by MATLAB. For the general shape of the circuit only latitude and longitude data are enough so other details were excluded for the moment.

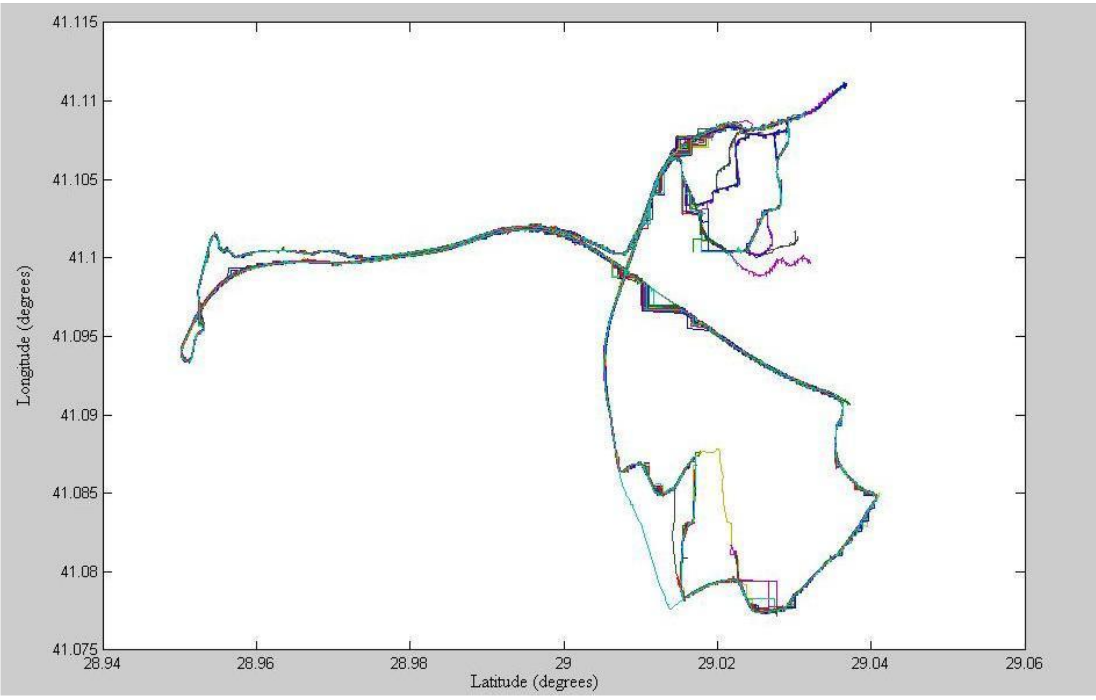


Figure 3.1: Geodetic (Decimal-Degree) Representation of 74 Drivers

Plot in Figure 3.1 is the representation of all 74 different driver routes in geodetic or decimal degree-format; this is a view where x-axis and y-axis can be thought as a longitude and a latitude themselves. So in this representation +y and –y are, at the same time north and south directions, whereas +x and –x replaces east and west directions as if the rotational axis of the Earth is perpendicular to the ecliptic plane.

To give a brief explanation of the plot, it can be categorized into 3 parts; closed looking route in northeast direction is the campus part and also the starting place, ‘knotted-string’ like part which is the highway and the bigger closed looking route in south is kind of town centre with denser traffic. A curve with all driver routes is in Figure 3.2.

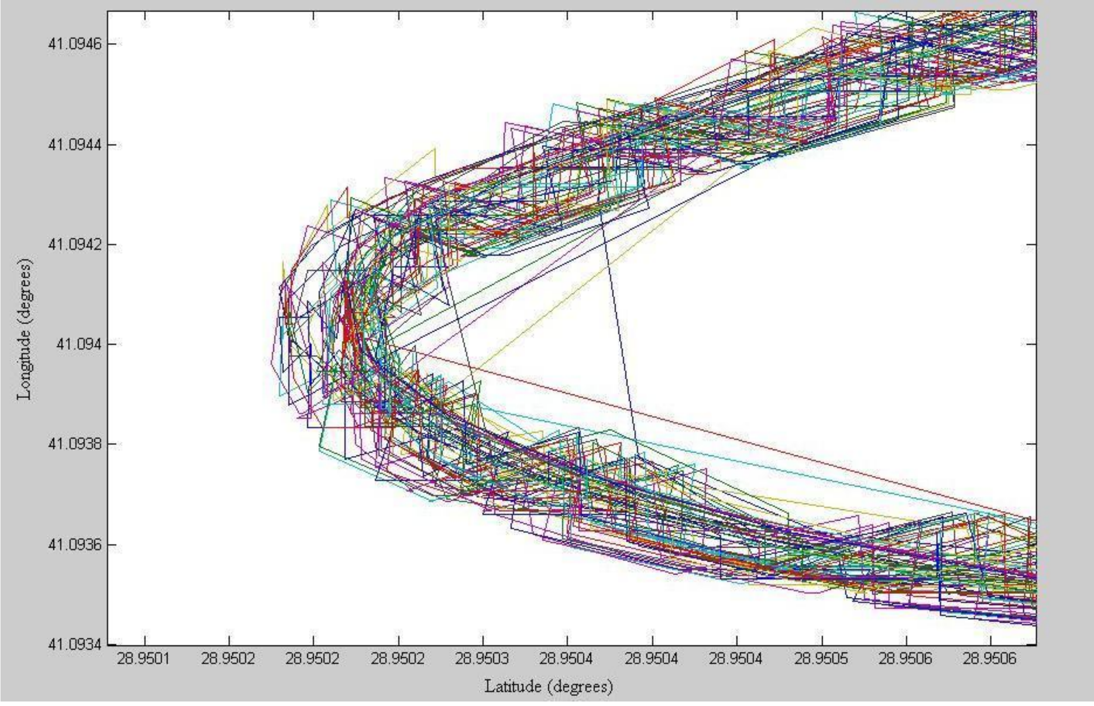


Figure 3.2: A curve with Decimal-Degree Representation

After plotting the coordinates and getting the general look of the circuit, more advanced equations were applied to the coordinates to get from geodetic coordinates to Cartesian coordinates. The difference was, eccentricity and curvature of the Earth were also taken into account to get realistic results. In simpler words, it is like taking the Earth right from the space and pop it flat out like a soccer ball on a surface. Below equations were used to get X, Y and Z coordinates [16];

$$X = \left(\frac{r_\varepsilon}{\sqrt{1-\varepsilon^2 sin^2 (Lat)}} + Alt\right) \cos (Lat) \cos (Lon) \quad \textbf{(3.1)}$$

$$Y = \left(\frac{r_\varepsilon}{\sqrt{1-\varepsilon^2 sin^2 (Lat)}} + Alt\right) \cos (Lat) \sin (Lon) \quad \textbf{(3.2)}$$

$$Z = \left(\frac{r_\varepsilon (1-\varepsilon^2)}{\sqrt{1-\varepsilon^2 sin^2 (Lat)}} + Alt\right) \sin (Lat) \quad \textbf{(3.3)}$$

‘Lat’, ‘Long’ and ‘Alt’ are shortenings for latitude, longitude and altitude, where as ‘r_e’ and ‘ε’ stand for radius of the Earth and first eccentricity respectively. Calculations concerning these formulas were done via a specific function, which can be found in the appendix, in MATLAB and again plotted as X-Y graphs in Figure 3.3. It was noted the general shape of the plots are very similar but with Cartesian coordinates, the overall plot seems stretched and rotated. It is due to the curvature and eccentricity of the Earth but for clarity, simple decimal conversion is better. Nonetheless it should be highlighted that ECEF representation is important, especially when comparing with displacement plots in the next chapter.

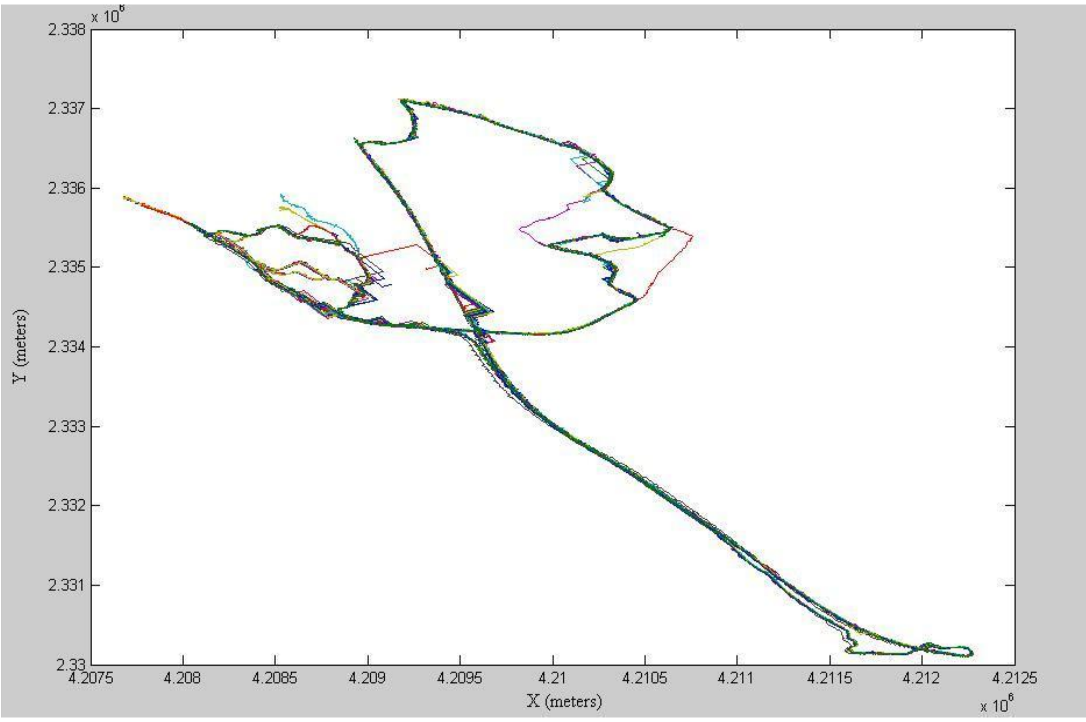


Figure 3.3: ECEF (Cartesian) Representation

Finally another representation format was used, aided by the commonly known 'GoogleEarth' program. Satellite images provide higher resolution and visuality while enabling people to understand the environment and topology better. 'GoogleEarth' accepts files which are in '.kml' format, changing the format from '.xls' to '.kml' was done with the help of the converter from EarthPoint's web site [17]. Decimal degree representations were given in '.xls' format and then converted to '.kml' with the help of this online converter toolbox. Normally Earthpoint requires certain donations to be made for the website, before being granted full access to its features, but for students and academical studies it is free. Contacting administers in these situations, lets that person to use contents of the website for a certain period of time, which can also be extended.

Results were satisfactory since the shape of the circuit was consistent with previous representations and coordinates fitted all roads and moves the car made, which are in Figure 3.4. In some places data points' precision became slightly distorted, at least error was more than the manufacturer's prediction of 40 centimeters but overall having coordinates on ‘GoogleEarth’ was useful, for it has some applications to be used. All coordinates can be viewed with degree/min/sec format which is hard to make in MATLAB, distance between points can be measured and altitudes of the points selected can also be shown graphically.

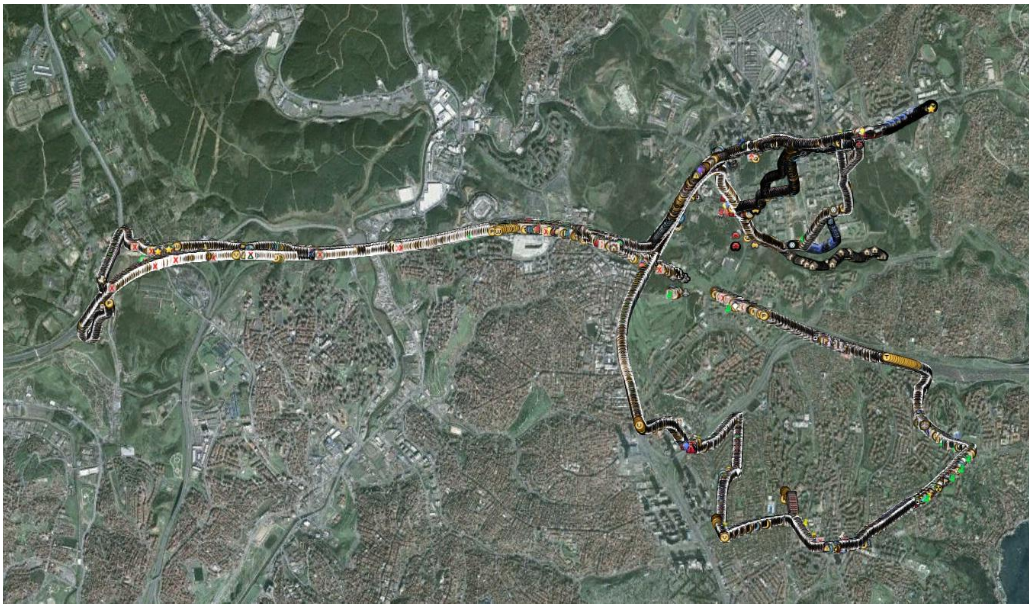


Figure 3.4: All routes on Google Earth

Converting tool on Earthpoint’s site has many features on GPS points like markers, headers or time zones, there are even some sub-categories under these. They all can be used, if written with their special format. These features can be added to the Excel file under their own header. For this project only ‘Icon’ and ‘Iconscale’ commands were used. ‘Icon’ command decides which marker should be put for current GPS data point. There are 570 different icons with their numbers to select from, so just putting a number besides a data point is enough, of course under the header ‘Icon’. ‘Iconscale’ command adjusts the size of the icon to be appeared, scale range is between 0-1. Since there are thousands of points, it is selected not too big but enough to be distinguished from others when zoomed in, so after some tries, 0.4 was found to be perfect size for the case. As zoom increases, this icon size effect gets important like in Figure 3.5.

While converting to ‘.kml’ files, a specific marker can be attached to the coordinate points which makes it easy to distinguish between different drivers’ points, as mentioned before this is done with ‘Icon’ command. Since all 74 drivers’ GPS data are plotted to a limited space, it is very difficult to separate them from one another. Even though there are half of the drivers in Figure 3.6, distinguishing them is hard.

Of course there is always the possibility to turn on or off specific coordinate sets for the sake of simplicity of the view.

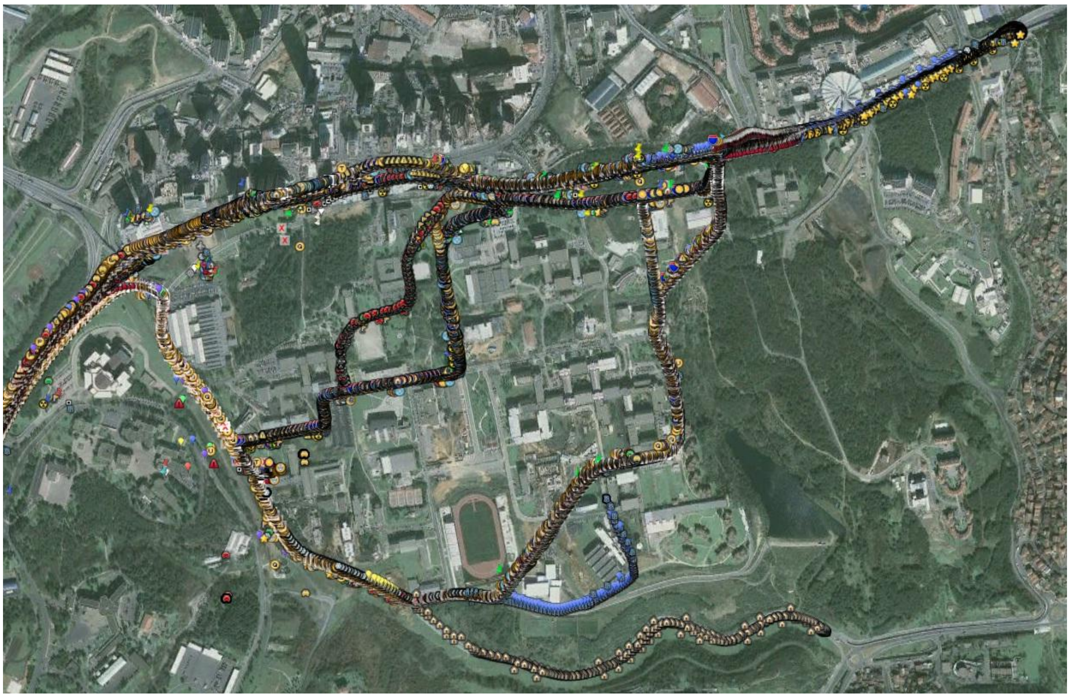


Figure 3.5: Google Earth view of ITU Ayazaga Campus

Figure 3.6: Zoomed image over E6 highway

3.3 Optional Approaches:

There is another position confirming method that requires more sophisticated GPS equipment, however determines locations much more precisely, though in a slightly different manner, than previous DGPS techniques. It is called Real Time Kinematic and requires at least two GPS units. Traditional GPS receivers compare the signal sent from satellites with their internal copy of the same signal and try to align them. Due to the time for the signal to reach from satellite to the receiver, there is always a delay but progressive delays will eventually make the signals lined up [18]. Maximum accuracy for this kind of tracking is approximately 30 centimeters.

RTK, on the other hand, as can be seen in Figure 3.7, uses a stationary GPS receiver as a base module that is both connected to the satellite and to a secondary GPS receiver like in Figure 3.8. Secondary GPS receiver takes relative location information from this base receiver via a radio modem. Though its actual position is as accurate as base receiver's, relative position can be determined close to a few millimeters. Plus these secondary, namely mobile, receivers can be multiple. There are useful applications suitable to this technique like surveying, mapping or local position controlling.

Figure 3.7: RTK Base Receiver

Figure 3.8: Mobile Receiver with Tracking Unit

An alternative coordinate system available, besides previous section, is ENU system, which is basically, Cartesian form of geodetic representation introduced earlier. Likewise its name leaves no doubt, since opening out it reads ‘East North Up’. Intuitive and practical format causes common utilization on local scales. ECEF or Cartesian and ENU coordinate systems are shown in Figure 3.9. Blue coordinate system represents ECEF or Cartesian, similarly green coordinate system stands for ENU coordinate system.

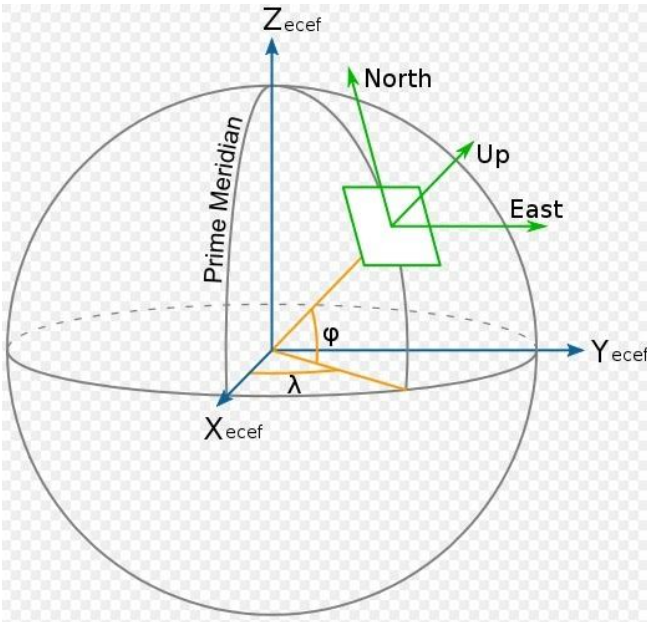


Figure 3.9: ECEF and ENU Coordinate Systems [19].

To get to ENU coordinates, there are two steps; first change geodetic to ECEF, in other words to Cartesian format, then multiply by a specific transformation matrix with respect to a reference point. Transformation matrix is below [20]:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} -\sin(Long_r) & \cos(Long_r) & 0 \\ -\sin(Lat_r)\cos(Long_r) & -\sin(Lat_r)\sin(Long_r) & \cos(Lat_r) \\ \cos(Lat_r)\cos(Long_r) & \cos(Lat_r)\sin(Long_r) & \sin(Lat_r) \end{pmatrix} \begin{pmatrix} X_p - & X_r \\ Y_p - & Y_r \\ Z_p - & Z_r \end{pmatrix} \quad \textbf{(3.4)}$$

Again ‘Lat_r’ and ‘$Long_r$’ refer to latitude and longitude of reference point, likewise coordinate subtraction matrix defines the difference between target point and reference point. In this trial, reference point is taken as the starting point of test drive, and since Z coordinates are not interested in, only [2x2] part of transformation matrix was used. As predicted, resulting plot in Figure 3.10 is identical to geodetic version in shape, but instead, this is in metric scale and ECEF format. Since its name being

ENU; up is north and right is east in this representation. As told before, this format is preferred for local application due to its simple look.

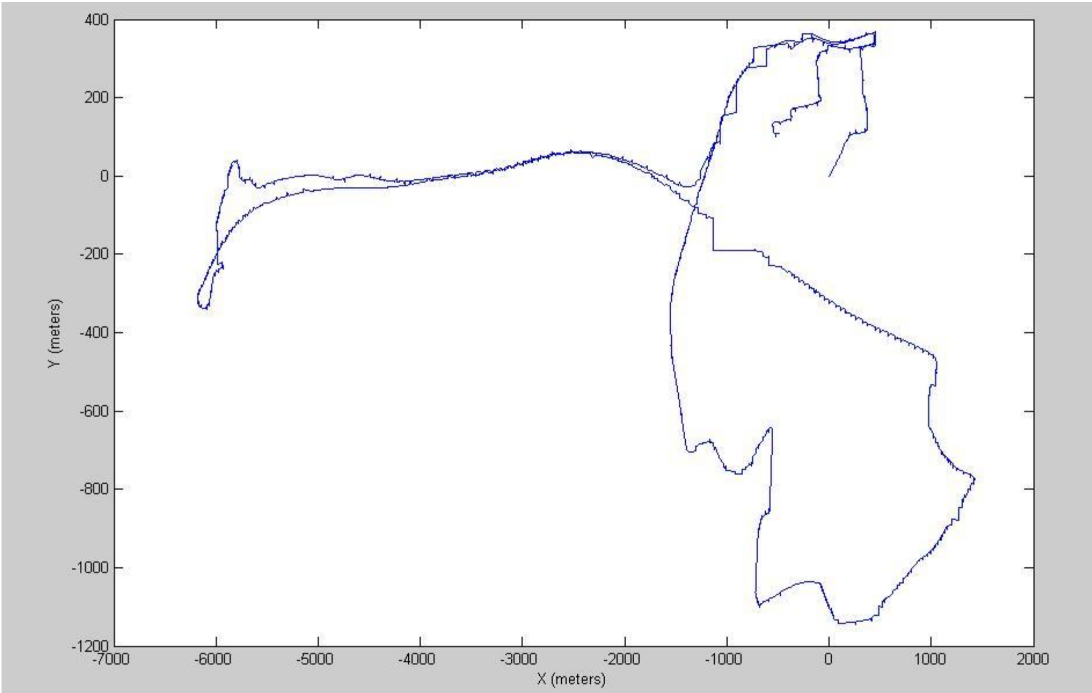


Figure 3.10: ENU Representation

4. COMPARISON OF EXPERIMENTAL AND SIMULATED DATA:

One of the scopes of this thesis was to compare and see, in what measure do the data collected during the tests, followed the pattern that is foreseen from the vehicle model. All automobile manufacturers start developing cars or safety systems, as a first step, with respect to a virtual model. Later on feedback gotten from these simulations give fundamental feedback about how to finalize project with desired specifications. Relation between real and virtual situations may or may not hold every time because there are unexpected or neglected variables that are not taken into account, but are present to influence the results.

Since GPS data type was one of the most important and closely examined data in this project, it was focused in this chapter too and correlated with other data types. Essential thing to be expressed was the shape of route of the test track. In the GPS analyses chapter, test track was clarified and verified using coordinates. It was also double checked using GoogleEarth, and seen all roads and curves fitted to the coordinates, not perfectly but clear enough to leave no doubt. From a different point of view, the route, namely position data can be considered a major data since speeds, accelerations and dynamical rates are all differentials of it.

4.1 IMU Sensor Approach:

First approach was through the IMU sensor, as it is obvious, IMU sensor records all x-y-z accelerations and roll-pitch-yaw rates with respect to time. So in theory, just by integrating from these values, it should be possible to access to position data, where it would be possible to plot a route from. Contents of ‘M3’ IMU sensor was explained before, in order to make necessary calculations, 3 rows of data were taken; x-acceleration, y-acceleration and yaw rate. As a first step, below equations were used to get speeds in x and y directions which are u and v [21];

$$a_x = \dot{u} - v.r \qquad \textbf{(4.1)}$$

$$a_y = \dot{v} + u.r \qquad \textbf{(4.2)}$$

After finding these speeds, it is just integrating one more time to get x and y positions, and sketch them in the right orientations. In order to accomplish this following model in Figure 4.1 was created in Simulink:

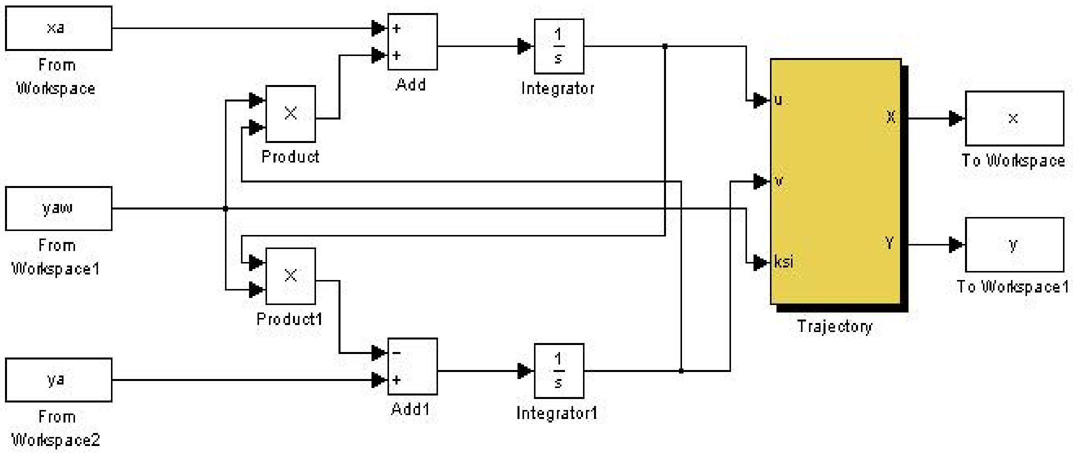


Figure 4.1: Simulink Model to get position from IMU Sensor Data

At the left side of the model there are 3 input signals coming from MATLAB workspace that are imported from ‘M3 IMU’ file; xa, ya and yaw. These are [25328x2] matrices, each sharing first row common as time values. Then according to the dynamic equations, math operations take place where ‘u’ and ‘v’, after getting out of the integrator is fed back to each others’ equation. Finally they are inserted into the trajectory plot where final integration occurs and position data is oriented with help of geometric adjustments. So in the end, from IMU data x and y displacement plot is generated as in Figure 4.2.

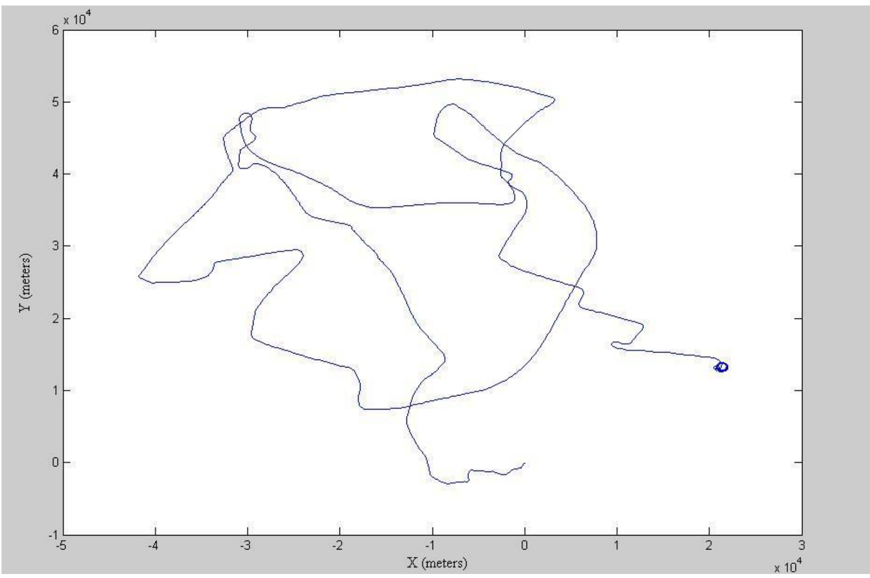


Figure 4.2: Graphical Representation of the Test Route with IMU Data

At first glance, plot in Figure 4.2 may seem to be irrelevant to the test route representations in GPS chapter. In fact this is true, since it does not show the correct path the car followed. If examined closely, some similarities can be noticed like the region where the car gets off and on again on the highway but in this case it seems inverted. The turning point is very characteristic where it crosses the opposite direction lane of the highway and looks like a knot. In real case, car crosses under the highway to the opposite side via a tunnel, so it is consistent with the pattern. Another familiar thing to note is the outer boundary of the plot; it looks like closed-loop but indeed, is not. This perimeter shaped route is a local copy of what was called as down town part of the original test route, again it is not oriented correctly.

Generally the plot seems to share some specific similarities with the original route but it is somewhat disoriented and looks interfered with one another. It is hard to realize for an ordinary eye. Most logical and probable reason is caused by the update rate of the device. According to the manual, IMU sensor is good for refresh rates greater than 100 Hz, so below this value, signal quality is decreased. So for a car that is being driven, IMU sensor gives best results for quick actions or rapid moves, which are in high frequencies in X-Y-Z directions. For example acceleration component in X direction, namely the acceleration of the car, is more perceivable from standing position or lower speeds than higher speeds. This is because effect of engine power on vehicle dynamics, lessens against increasing kinetic energy. Parallel to this fact, sensor sensitivity is better recorded when turning a tight turn than a wide turn. Steering effect is very rapid in these situations, also tight turns or acute angled curves are mostly taken with lower speeds which further backs up the idea.

This sampling time problem may be the cause of scrambled look of the plot. When looked closely, it is obviously visible that both highway parts are missing. This draws attention since in these regions vehicle has a relatively high speed and most of time, common driving manner is calm. So these conditions may cause the IMU sensor to record badly and this could be reflected to the plot as missing displacements. Long highway roads which are driven with high speeds are missing in IMU graph and addition of other regions build up errors and result in a chaotically merged plot.

It should also be noted that during these calculations acceleration in Z axis is neglected. X-Y plane’s state is considered unaffected though changes in Z acceleration causes coordinate axes to change orientation, meaning X-Y plane does not always stay parallel relative to ground. Error percentage due to this problem adds up as the car experiences more Z acceleration. Altitude data show that car travels approximately over 100 meters in Z direction so it might be responsible for the corrupt route. Graphical proof is in Figure 4.3 where it shows Z acceleration that is supposed to read 1 g as the effect of gravity, but graph shows it has been changed a lot during the test.

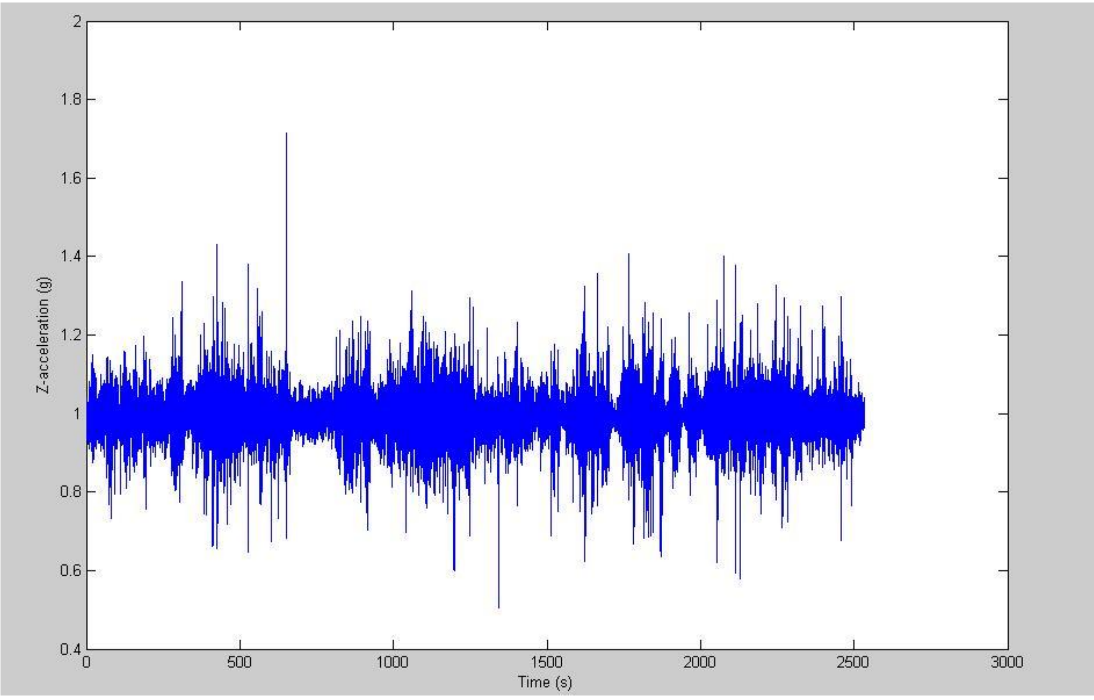


Figure 4.3: Z-Acceleration During Test Drive

4.2 Vehicle Model Approach:

Model based simulations are widely used in automotive industry as computer aided simulation programmes advanced in time. Especially for new technological developments in cutting edge car systems, simulations are cost-friendly and time saving. Traction/Stability systems, active cruise control systems or collision warning systems could be given as examples for this kind of work, where simulation study is crucial. Models could differ according to their purpose of use, but basically there are two types; single and double track. Single-track model, also referred as the bicycle model, regards two consecutive tires like on a bicycle or motorcycle, set to show acting forces and moments on each tire and vehicle body. Similarly in a double-track model, there are four wheels, which is more suitable while working on cars.

Analyzation and calculation are done exactly the same way, but of course addition of an extra pair of tires changes the equations.

In Figure 4.4, there is a representation of a double track vehicle model, as it makes a certain steering angle with its front tires. This is a typical situation during taking a curve with a car. Forces acting on each tire and vehicle's velocity components, as well as yaw rate can be seen. Nomenclature for the model is given in Table 4.1.

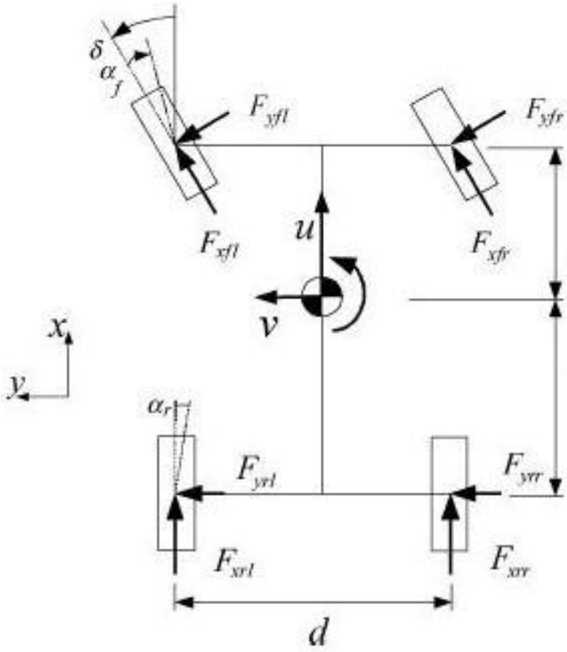


Figure 4.4: Double-Track Model of a Vehicle in Yaw Plane [22]

This vehicle model has a 3 degree of freedom (DoF), which are translational motion in X and Y directions and one rotational motion around Z-axis. So its equation representation is [23]:

$$m\dot{u} = F_{xr} + F_{xf}cos(\delta) - F_{yf}sin(\delta) + m\gamma v \quad \textbf{(4.3)}$$

$$m\dot{v} = F_{yr} + F_{xf}sin(\delta) + F_{yf}cos(\delta) + m\gamma u \quad \textbf{(4.4)}$$

$$I_z\dot{\gamma} = aF_{xf}sin(\delta) + aF_{yf}cos(\delta) - bF_{yr} + \frac{d}{2}\left(F_{xfr} - F_{xfl}\right)cos(\delta) + \frac{d}{2}\left(F_{xrr} - F_{xrl}\right) \quad \textbf{(4.5)}$$

F_x is the longitudinal forces acting on the tires and they are distinguished by naming fr (front left), fl (front right), rl (rear left), and rr (rear right). It is obvious from the representation that longitudinal forces acting on front tires are $F_{xf} = F_{xfr} + F_{xfl}$, likewise lateral forces are $F_{yf} = F_{yfr} + F_{yfl}$. For small slip angles, lateral tire forces are given as follows:

$$F_{yf} = C_f\left(\delta - \frac{v+\gamma a}{u}\right) \tag{4.6}$$

$$F_{yr} = C_r\left(\frac{\gamma b - v}{u}\right) \tag{4.7}$$

Finally substituting equations (4.6) and (4.7) into (4.3), (4.4) and (4.5) and using small angle approximations, vehicle model is represented as below:

$$m\dot{u} = F_{xr} + F_{xf} - C_f\left(\delta - \frac{v+\gamma a}{u}\right)\delta + m\gamma v \tag{4.8}$$

$$m\dot{v} = C_r\left(\frac{\gamma b - v}{u}\right) - C_f\left(\frac{v+\gamma a}{u}\right) + (C_f + F_{xf})\delta - m\gamma u \tag{4.9}$$

$$I_z\dot{\gamma} = aF_{xf}\delta + a.C_f\left(\delta - \frac{v+\gamma a}{u}\right) - b.C_r\left(\frac{\gamma b - v}{u}\right) + \frac{d}{2}\left(F_{xfr} - F_{xfl}\right) + \frac{d}{2}\left(F_{xrr} - F_{xrl}\right) \tag{4.10}$$

Table 4.1: Nomenclature For Double-Track Model

a	Distance from center of gravity to front axle	I_z	Moment of Inertia About Yaw Axis
b	Distance from center of gravity to rear axle	m	Mass of the Vehicle
d	Tread (Track Width)	u	Vehicle longitudinal velocity, positive forward
C_f	Front Tire Cornering Stiffness	v	Vehicle lateral velocity, positive toward left
C_r	Rear Tire Cornering Stiffness	γ	Yaw rate, positive CCW
F_{xf}	Front Tire Longitudinal Force	δ	Tire Steer Angle
F_{xr}	Rear Tire Longitudinal Force		
F_{yf}	Front Tire Lateral Force		
F_{yr}	Rear Tire Lateral Force		

For this thesis, a double-track vehicle model was used that was specifically designed to meet test car’s specifications [24]. Model was created in Simulink and consisted of two blocks as seen in Figure 4.5. Orange block can be stated as input block and blue block is where outputs are stored.

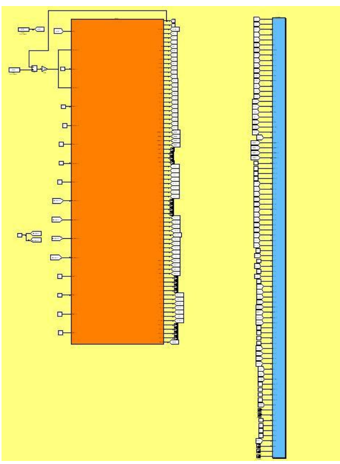


Figure 4.5: Simulink Diagram of ‘Uyanık’ Vehicle Model

This is a rather complex model that was created step by step over a respectively long period of time. Technical details and its inner working algorithms are out of scope of this thesis. Briefly it holds every aspect of typical double track model. Vehicle dynamics is the focus of the model which is stored in input block. What it contains are tire model, tire vertical forces, vehicle and suspension dynamics, namely all the necessary information to simulate correctly that is seen in Figure 4.6.

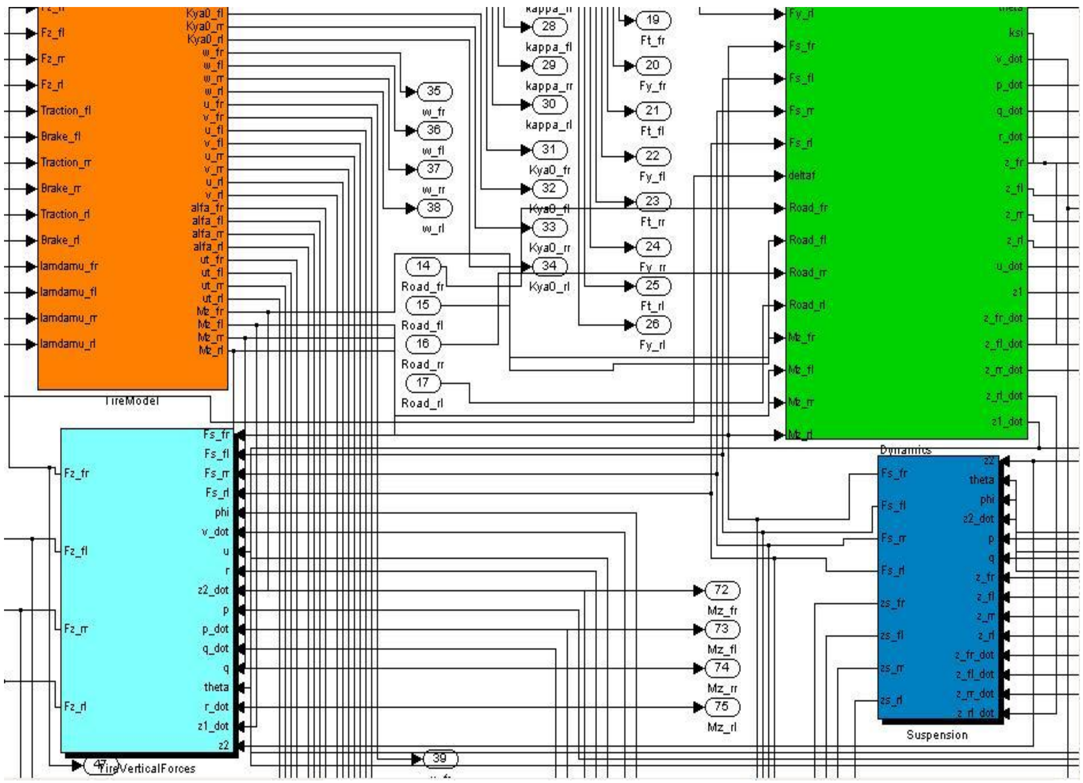


Figure 4.6: Contents of Input Block

Vehicle model represents the simulation part of the analyses, it’s an idealized environment where pre-assumptions and pre-calculations form a virtual car that can be controlled and react accordingly. There are two major inputs introduced to this double-track car model, needed to simulate nearly every data about the car: steering angle and vehicle speed. With these data fed to the vehicle model, it can be simulated as if the car really completed the track with real driving profile.

At this point experimental and virtual data combine and result mutually. Input data, which are steering angle and speed, are taken from real life test data that are stored in CANBUS files of every test driver. In fact, they are two columns in CANBUS files although there are some precautions about them, such as, instead of steering angle there is steering wheel angle stored. So this set of data must first be divided by steering gear ratio and then converted to radians, similarly vehicle speed column must be processed in order to change it from kilometers per hour to meters per second. After these minor operations, data sets are ready to be inputted to the model.

Data are simply imported to MATLAB from Excel and with the help of ‘simin’ blocks, they are fetched into the model in Simulink. Input part of the model is clear on where or how to connect. One thing to note is that for vehicle speed input, to improve signal quality and get realistic results, there is a proportional controller with a gain K, embedded to the model at the left side of Figure 4.7. This controller takes the negatively fed back speed from the model then subtracts from experimental speed and multiplies the difference with a constant K. Result is inputted as traction to the left and right frontal wheels, so if speeds coming from data and model match, then there is no traction. Idea behind is simple, to make vehicle model speed follow experimental speed, because since speed is differential of position, correctly matched speed data is necessary for a realistic trajectory.

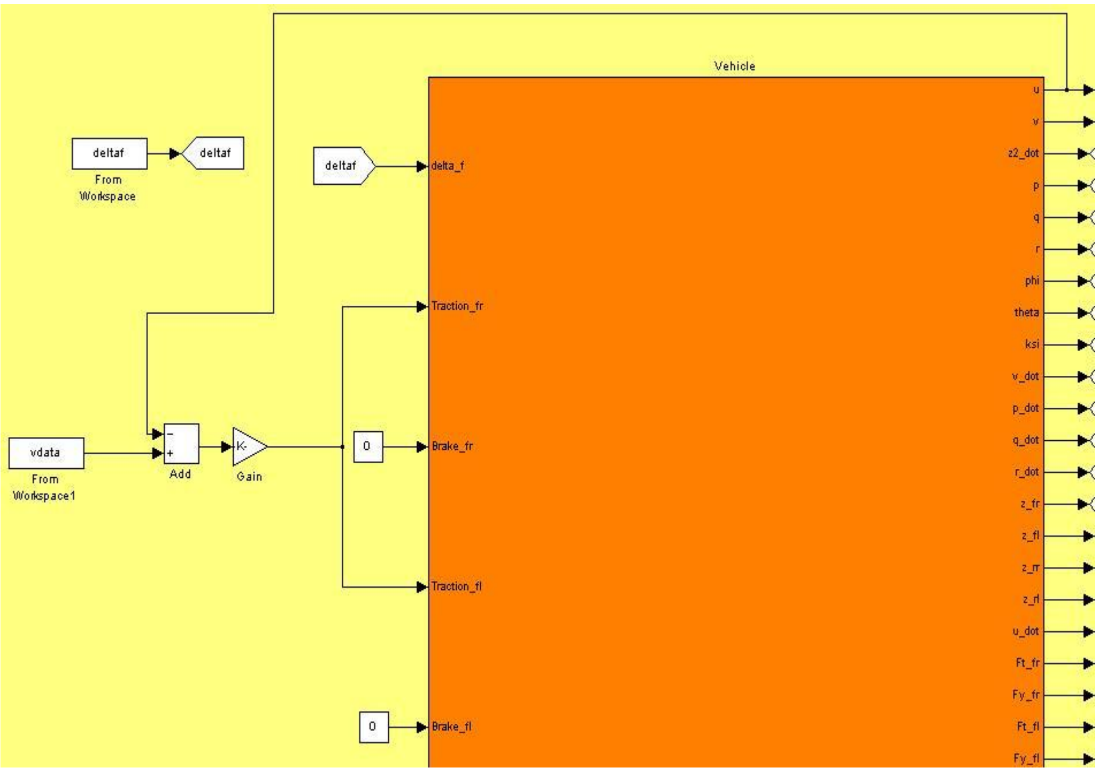


Figure 4.7: Inputs Given to Model and Addition of Proportional Speed Controller

Before running simulation, one more thing has to be done, which is assigning constant values of test vehicle like weight, tire dimensions, suspension or aerodynamic properties. This is done via running a specifically prepared m-file called as ‘parametreMegane.m’ which can be found in the appendix and then everything sets ready. First objective was to determine the proportional controller’s gain K that would give the best course plot. Many trials were performed to see their effect on the displacement plot. Since displacement is outputted from the vehicle model as X and Y, only thing to do is plot them from command window. K=0, K=100, K=200, K=300, K=350, K=400, K=450 and K=500 values were tried one by one, and their plots can be seen below. Best result was gotten with K=400 among them, plots got erroneous and inaccurate as value changed from this point.

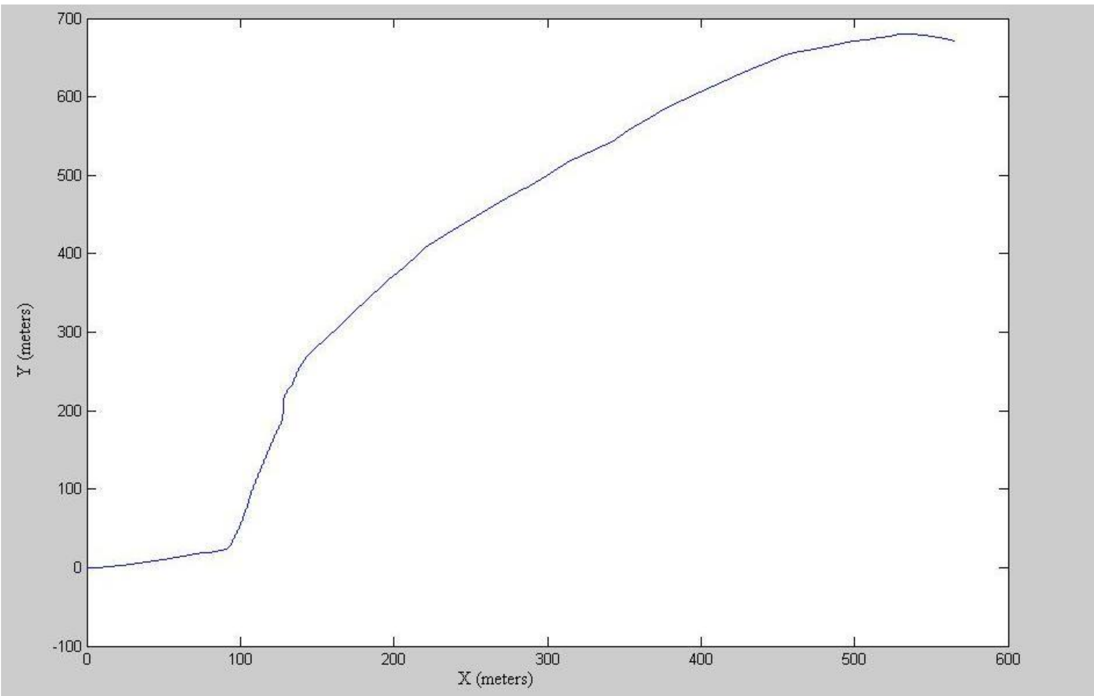
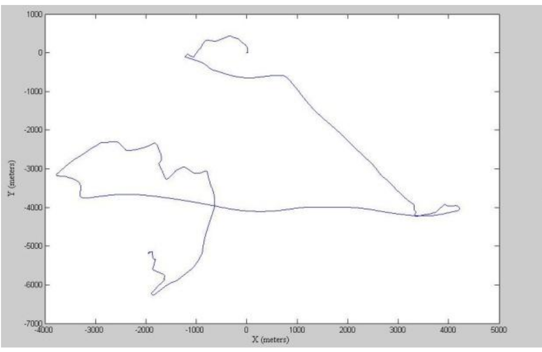


Figure 4.8: Trajectory Plot with K=0

When K is taken zero, as a beginning value, there is no chance of matching experimental and model speeds. So errors build up and cause a very misguided plot, as it can be seen in Figure 4.8, it isn't even a closed route.



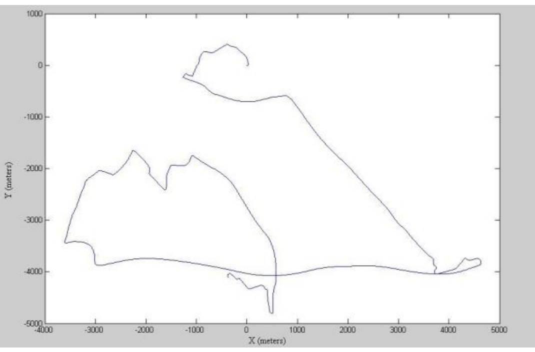


Figure 4.9: Trajectory with K=100 **Figure 4.10:** Trajectory with K=200

As K gets increased in Figures 4.9 and 4.10, characteristic trajectories start to form which are very similar to GPS plots. Plots carry every single detail from GPS plots like turning points and flat roads but orientation is false. First of all starting point and finishing point supposed to be very near to one another because they are within the boundaries of İ.T.Ü Ayazağa Campus, but they seem to be separated far too much. Upper part of the plot which is the beginning of the test, should lie below the other part, so that causes the major orientation problem.

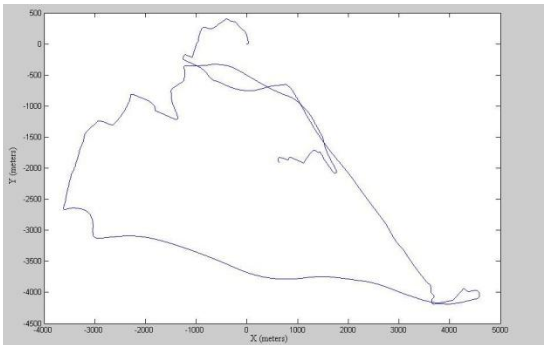


Figure 4.11: Trajectory with K=300

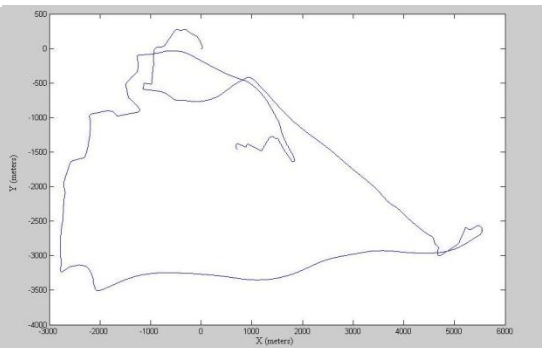


Figure 4.12: Trajectory with K=350

As values are further increased in Figures 4.11 and 4.12, below part becomes more dominant and engulfs the beginning part in itself. If checked from the GPS plots, it can be noted below part starts to take its original form, though still upper and down parts must interchange positions.

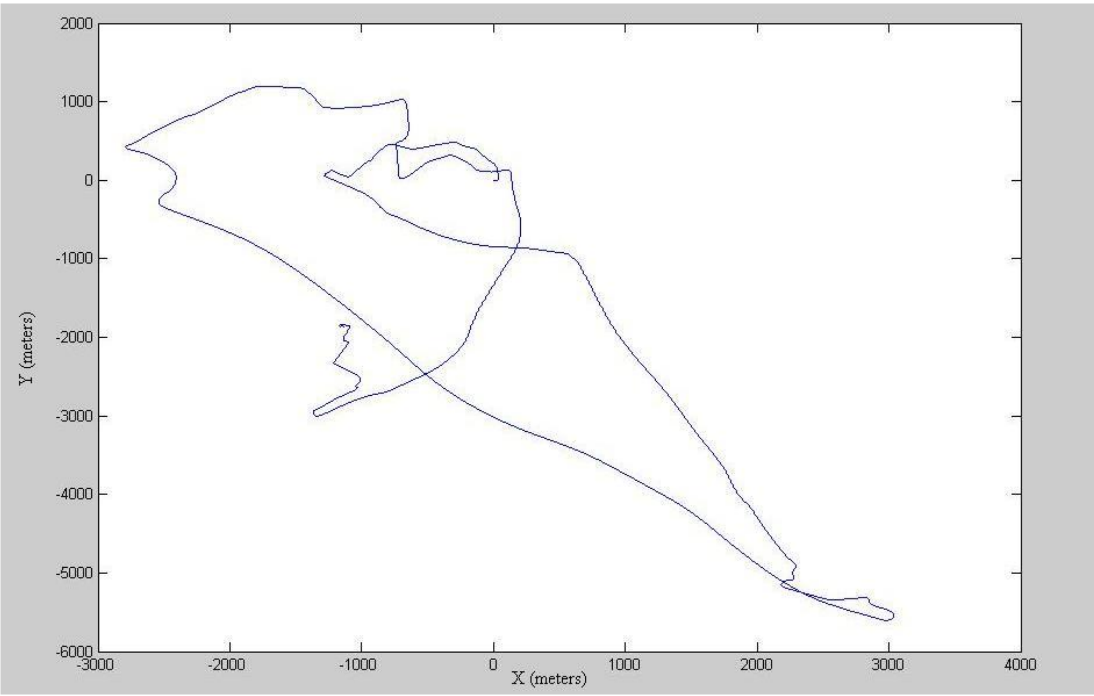


Figure 4.13: Best Fitting Trajectory with K=400

After numerous tries K is set for 400, and resulting plot in Figure 4.13 is the most satisfactory so far. Overall shape of the original GPS plot seems to be passed neatly, scaling and geometry of test track parts are acceptable too. Unfortunately major orientation problem still survives with newly changed K value. Difference is lessened but starting part of track should be way down the other part. Even with improved gain, start and finish points are in separate locations.

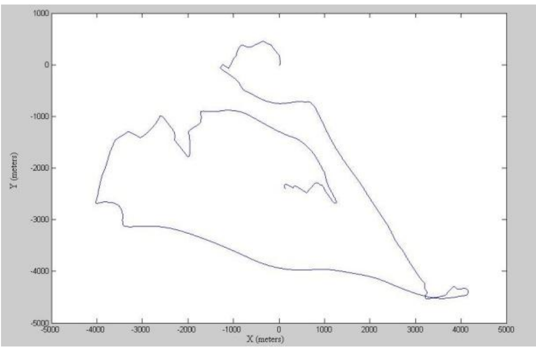


Figure 4.14: Trajectory with K=450

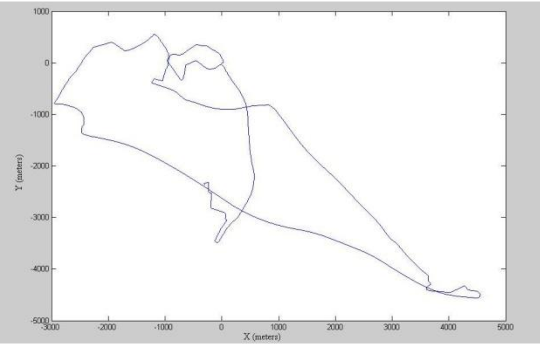


Figure 4.15: Trajectory with K=500

Values greater than 400 like in Figures 4.14 and4.15 do no good either, K=400 is a value that stands in between and has no alternative. Another thing to notice is, adjusting gain values doesn’t always give stable results, as in the examples, for K=450, plot seems to get separated but at K=500, they converge again. For values K>500, simulation gives ‘divide by zero’ error due to surpassing internal limits. So final and best result stays with K=400 even though it has some flaws.

5. HISTOGRAM ANALYSES:

Even though automobile technology advances day by day, there are still people present to operate them, naturally with certain margin of error. Focusing only on vehicle and driving dynamics is not enough for developing efficient safety systems. Man and vehicle must be thought in coalescence and since variations of these combinations could be millions, created systems must be flexible enough to tolerate them all. It should not be forgotten that humans are complex beings and may act unexpectedly or faulty in some situations, such as traffic.

Distinguishing and classifying driver behavior is a key concept in automobile safety, enabling the vehicle to act according to its driver and environment. If there is a reference pattern for all kinds of activities during a drive, then it is easy to decide and respond when these activities go off their usual courses. To examine driving patterns through drivers, another technique, widely used in the area of statistics, was applied to DriveSafe data, known as histogram.

Histogram is a graphical representation that highlights the frequency distribution of data [25]. It gives how many data are there, in user-specified and equally generated gaps between upper and lower bounds in a data set. These gaps, also called ‘bin widths’, are created by a parameter ‘n’ which is known as ‘number of bins’. So upper and lower limit difference of a data set divided by this ‘n’ value gives bin width. Naturally as number of bins increase, resolution of the graph does as well.

MATLAB interface of histogram is pretty simple, only difference from plotting a normal graph is, using ‘hist’ command instead of ‘plot’, also number of bins must be introduced too. For DriveSafe project, distinct data types from CANBUS file were selected that were thought to reflect the driver characteristics most, and their histograms were created. These data types are steering angle, vehicle speed, gas pedal press percentage and brake pedal press numbers. All these histograms were created for 6 drivers of whom 3 female and 3 male, number of bins used was n=20.

5.1 Steering Angle:

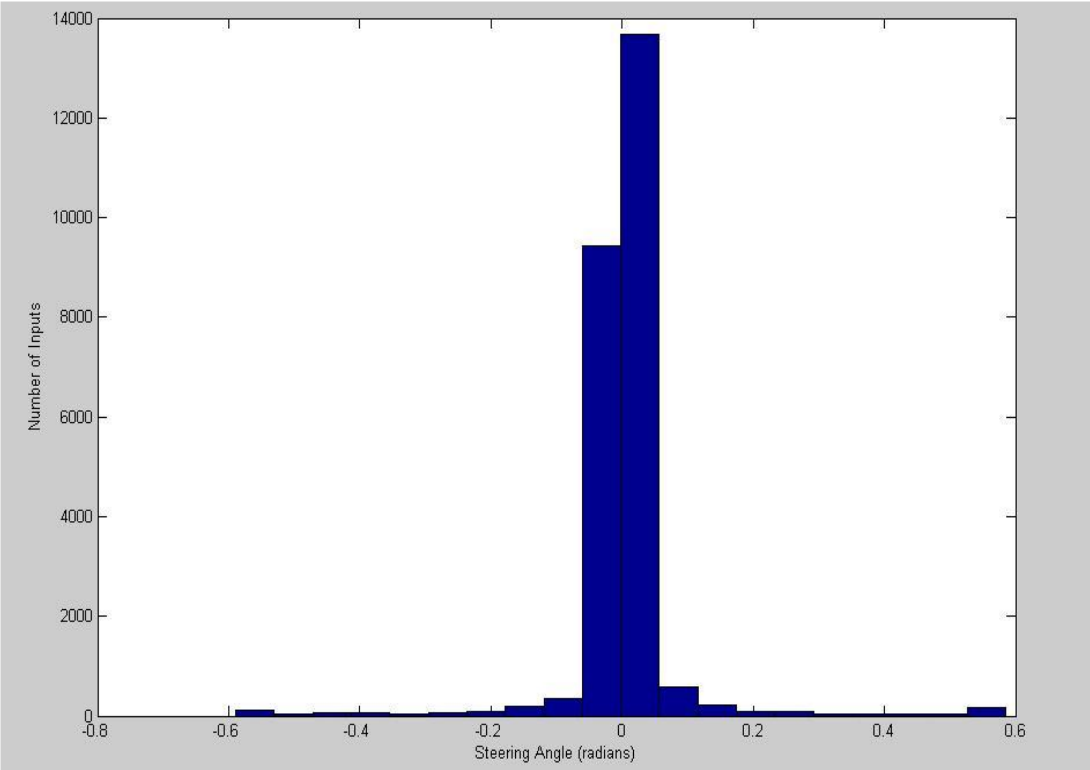


Figure 5.1: Steering Angle Histogram of Driver F1003

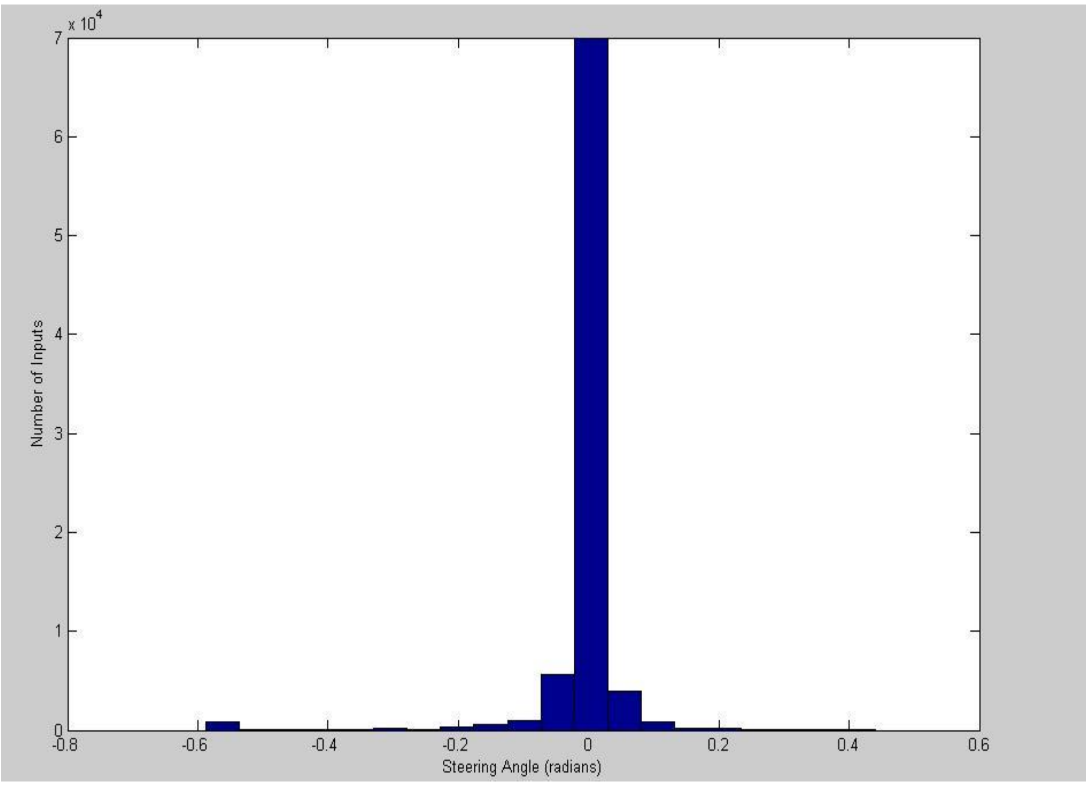


Figure 5.2: Steering Angle Histogram of Driver F1012

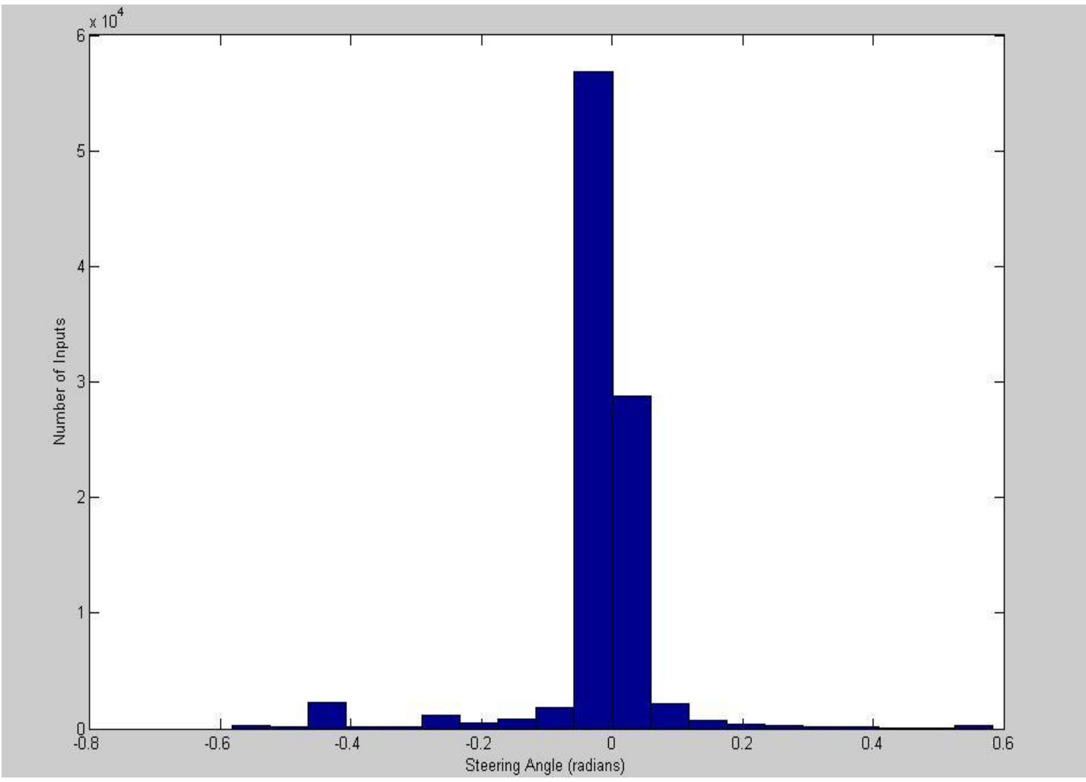


Figure 5.3: Steering Angle Histogram of Driver F1019

First three female driver steering histograms are above in Figures 5.1-5.3, from where it can be seen that graphs are roughly symmetric though there are some slight differences between positive and negative sides, resulting mainly from the test circuit being round shaped and thus car turning in one direction more than the other.

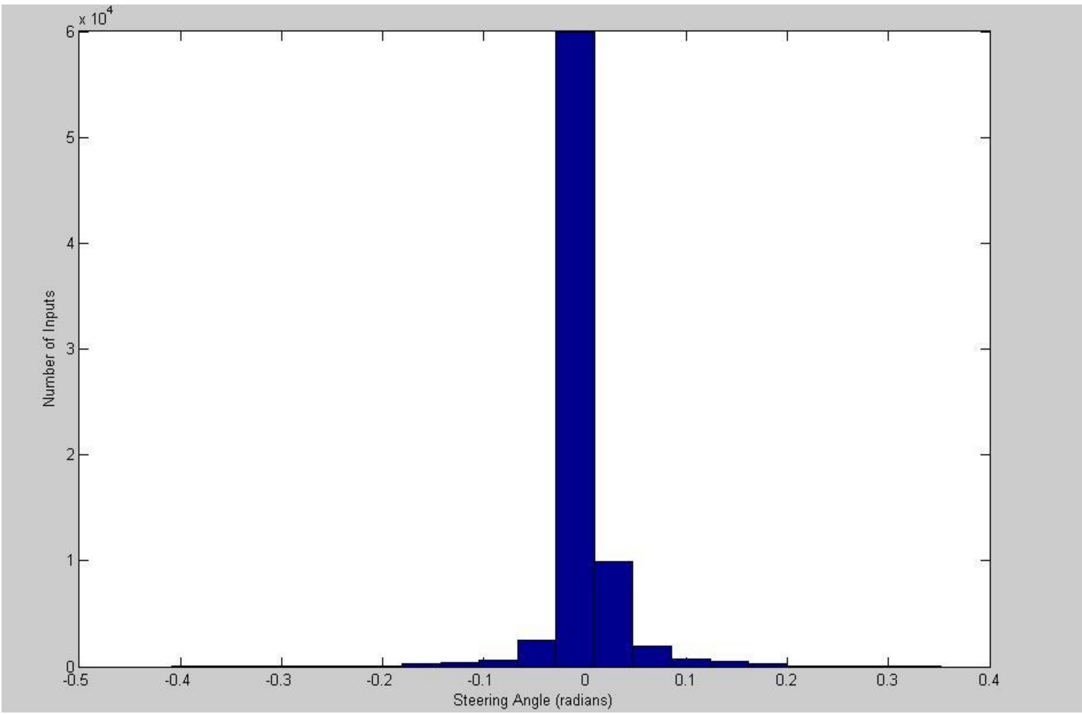


Figure 5.4: Steering Angle Histogram of Driver M1049

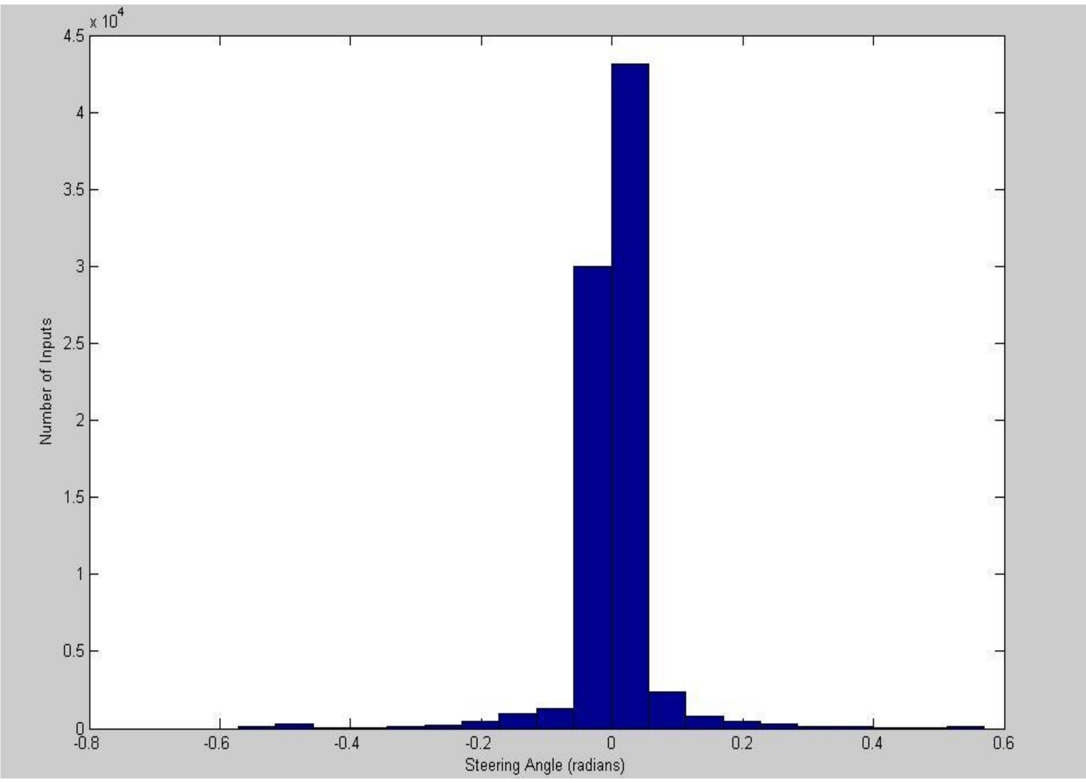


Figure 5.5: Steering Angle Histogram of Driver M1066

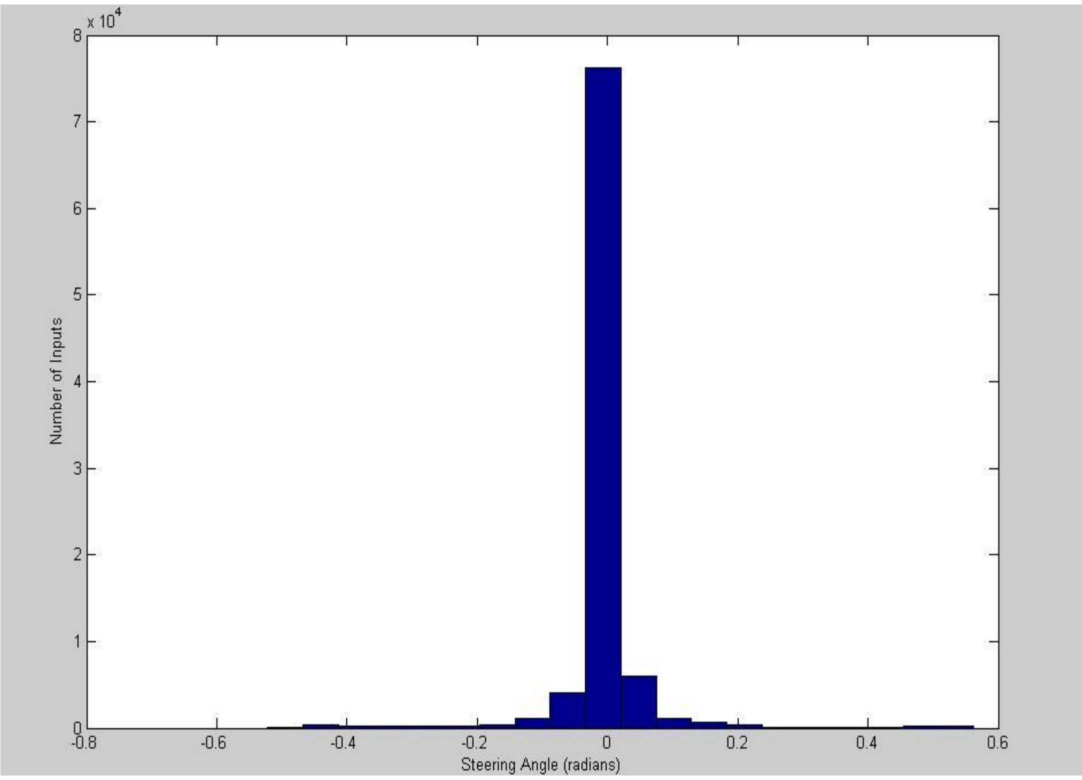


Figure 5.6: Steering Angle Histogram of Driver M1089

Male drivers' histograms in Figures 5.4-5.6, show no major differences from female ones; steering range differs between -0.6 to 0.6 radians which is approximately between 35 degrees in opposite signs. This is a normal value for front wheels unless there are precise maneuvers done in tight spots like getting out of very narrow parking lots.

Noticeable enough, around zero value which is the upright position of both front wheels and steering wheel, for some drivers there are two bars and for others there is only one. This might tell some drivers spend more time struggling to keep the car in its lane. This is a common problem for some people, at the same time a threat for others. To avoid this problem, car manufacturers developed lane assist systems, which with a special image processing unit, watches the road and lane lines and in case of crossing these lines with wheels, warns the driver with image, sound and vibration coming from the steering wheel.

Among these test drivers, a lane assist system would be recommended for drivers F1003, F1019 and M1066 with two bars around zero. From vehicle speed data presented below, it is clear lane keeping problem is not strongly related to speed. Fastest driver M1049 does not experience this problem, so does M1089 which is slow comparing.

5.2 Vehicle Speed:

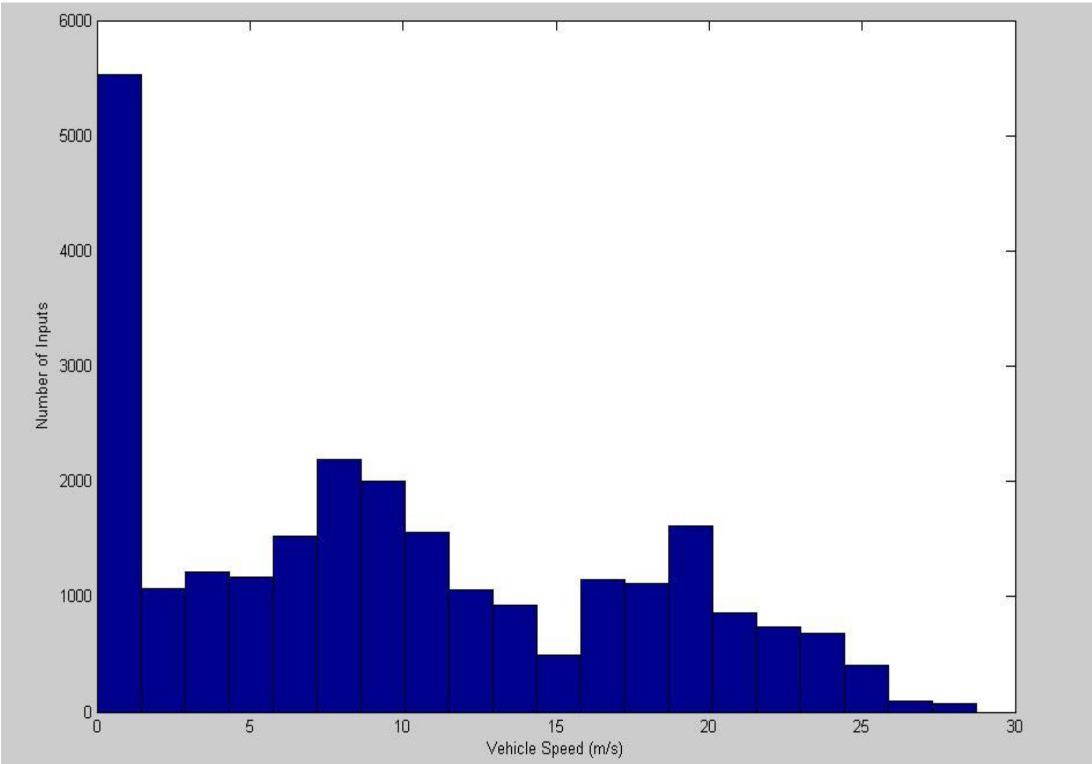


Figure 5.7: Vehicle Speed Histogram of Driver F1003

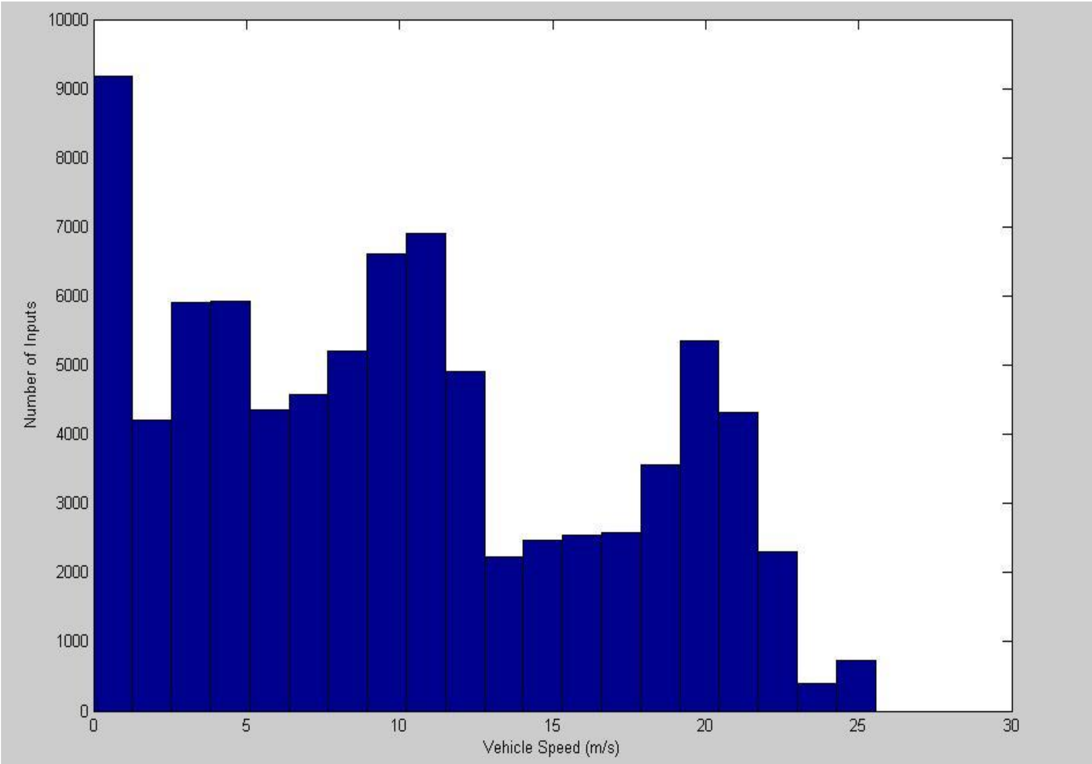


Figure 5.8: Vehicle Speed Histogram of Driver F1012

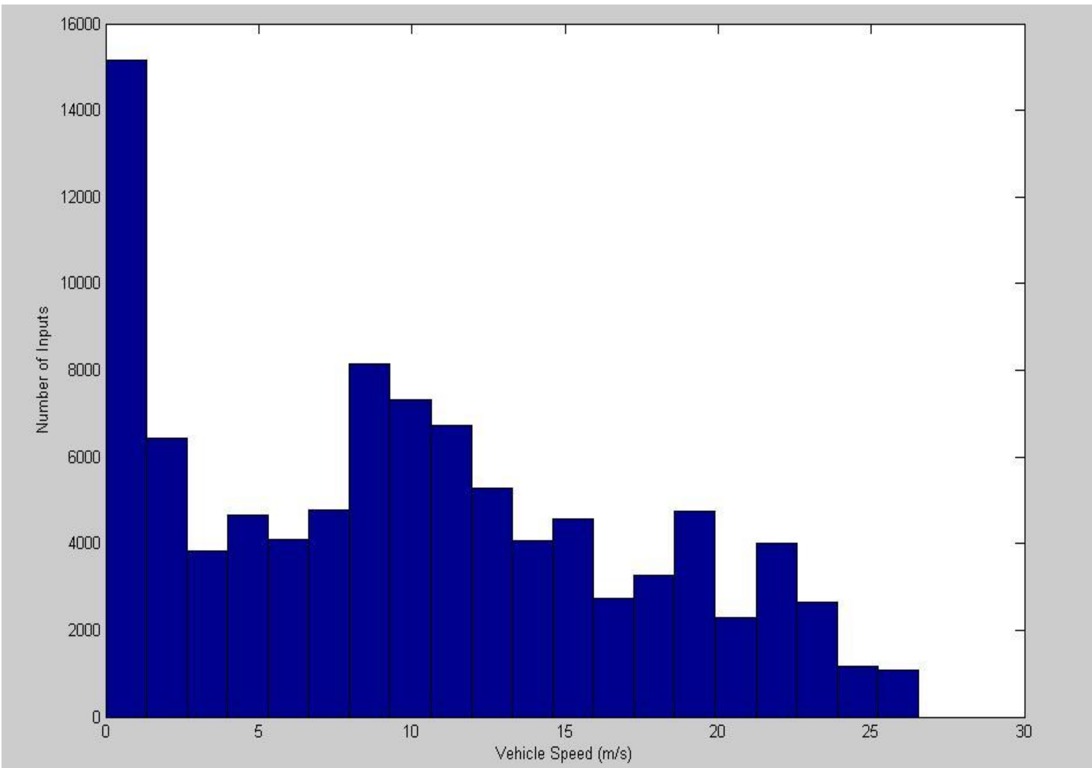


Figure 5.9: Vehicle Speed Histogram of Driver F1019

Vehicle speed histograms in Figures 5.7-5.9 show, most of the time speed is between 0-5 m/s which caused by traffic, and bars indicate that F1012 driver is slightly faster than its female colleagues. Their average speeds are respectively 9.62 m/s, 10.05 m/s and 9.99 m/s. Even though slowest driver is F1003, it made the highest top speed, so this shows F1003 is inclinable to fast driving, mostly when the road is permitting like E6-TEM part of the test track.

Spotting people's potential of doing excessive speeds is more serious than it sounds, since speed is one of the key elements for accidents to happen. Sometimes people are just too ignorant of the rules and they want some kind of excitement, but sometimes especially on highways they can go over speed limits without knowing. Both situations are dangerous and there are some systems on automobiles to prevent these from happening like self speed limiters and cruise controls.

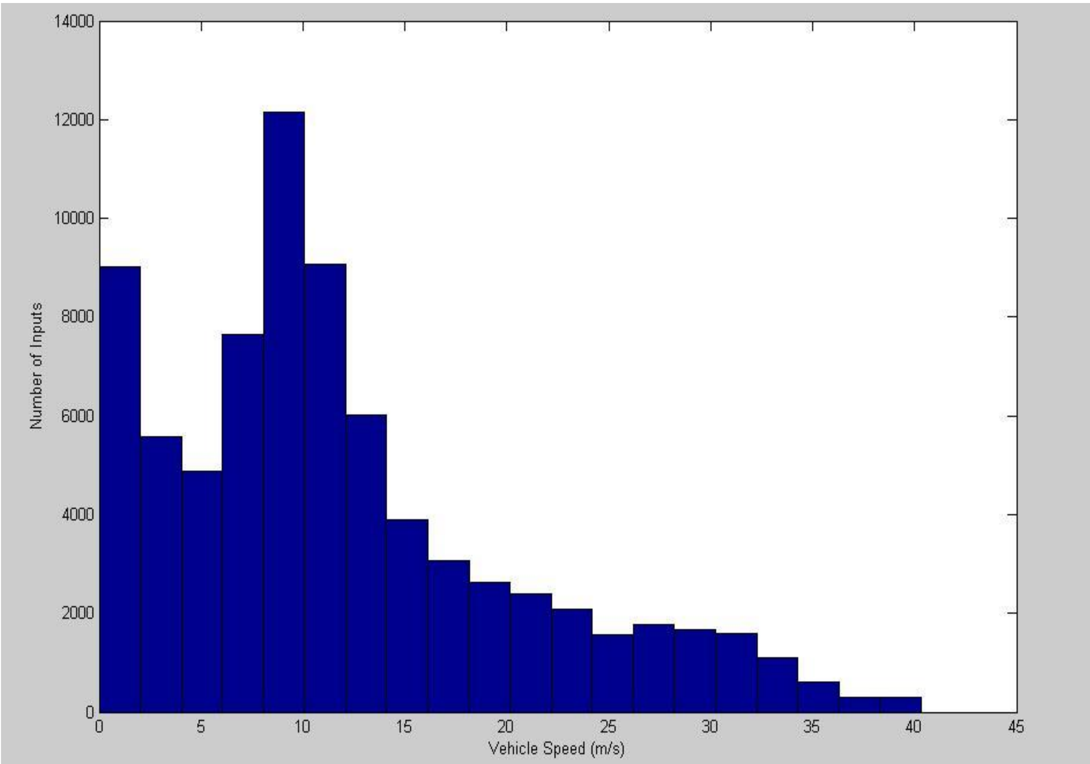


Figure 5.10: Vehicle Speed Histogram of Driver M1049

Male drivers' average speeds are 11.88 m/s, 11.38 m/s and 9.35 m/s as in Figures 5.10-5.12, apart from the last driver; male drivers are much faster than female drivers. Maybe difference seems little and can be thought to have no effect but for DriveSafe test track, it can mean time periods of up to 10 minutes. Despite last male driver, male average with 10.87 m/s is greater than females with 9.87 m/s and it can be concluded men being faster than women hypothesis is true.

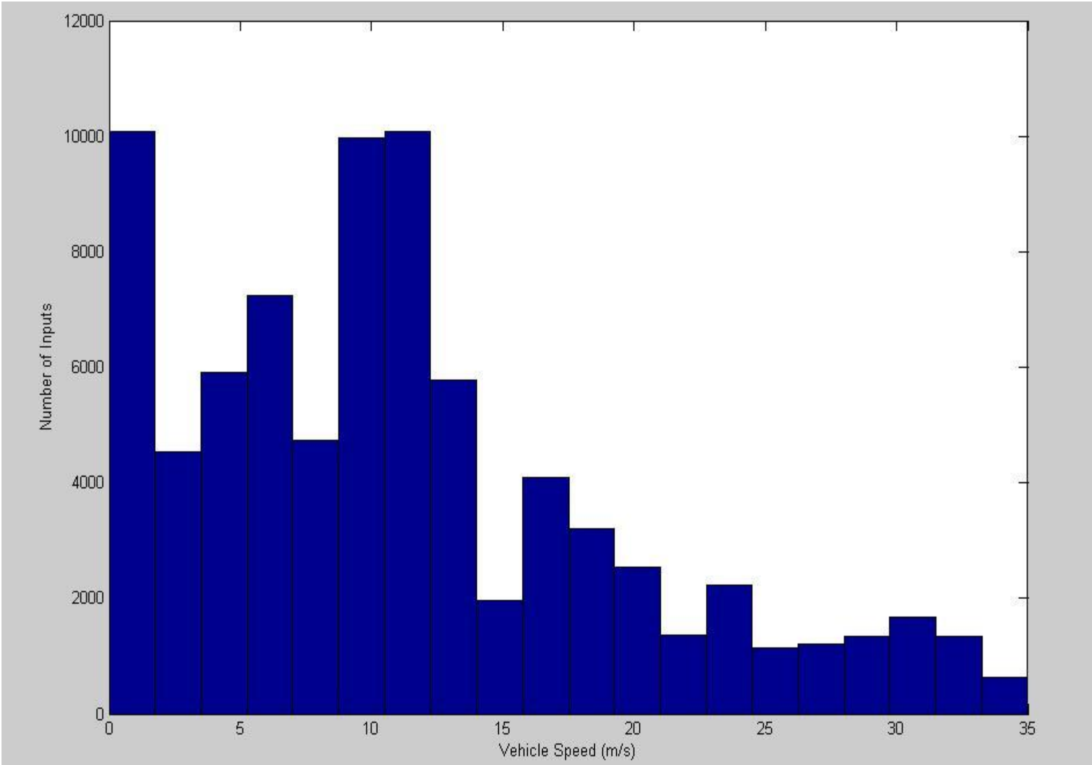


Figure 5.11: Vehicle Speed Histogram of Driver M1066

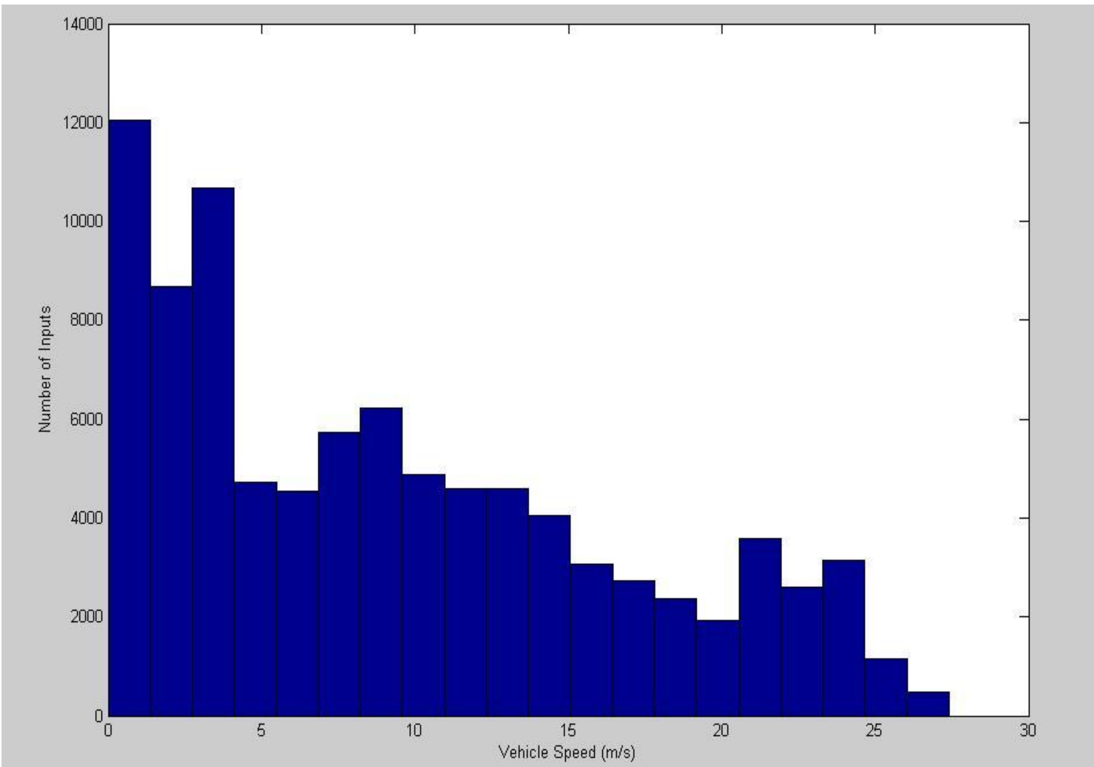


Figure 5.12: Vehicle Speed Histogram of Driver M1089

Maybe leaving speed control of automobiles to people is not always a good and trusting idea. They might decide to disagree or ignore speed limits, so for this reason in the future, every car might be installed with automatic self speed limiters that can act accordingly to its driving profile.

5.3 Percentage Gas Pedal:

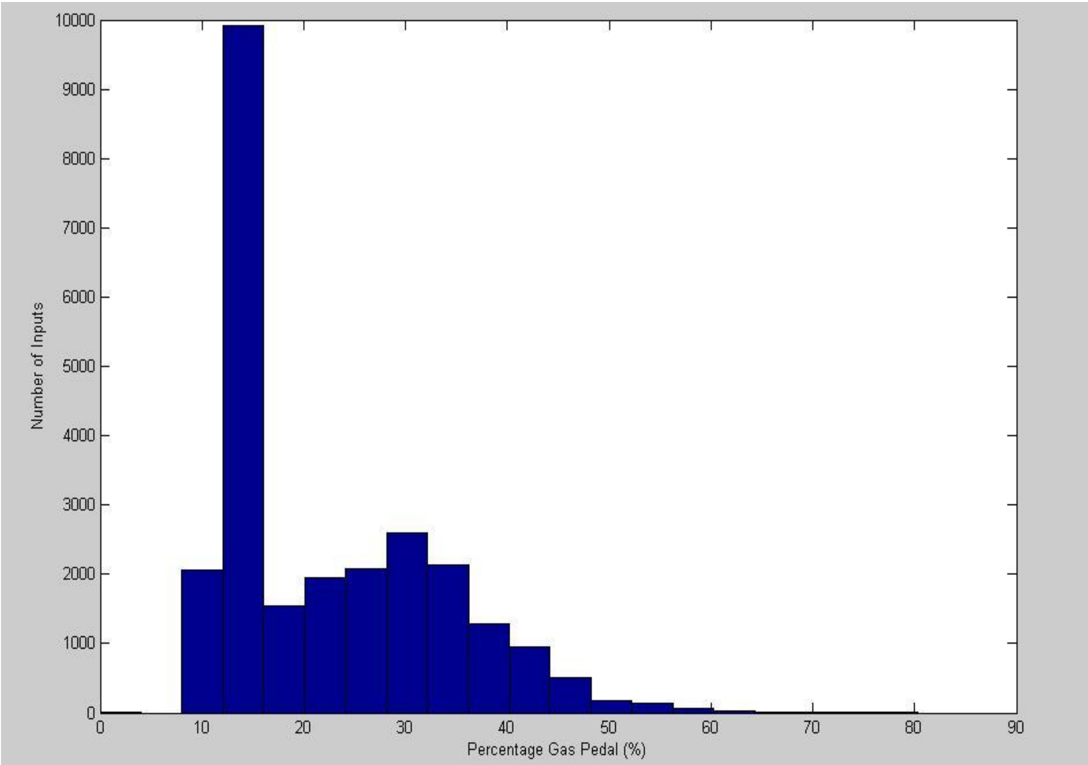


Figure 5.13: Percentage Gas Pedal Histogram of Driver F1003

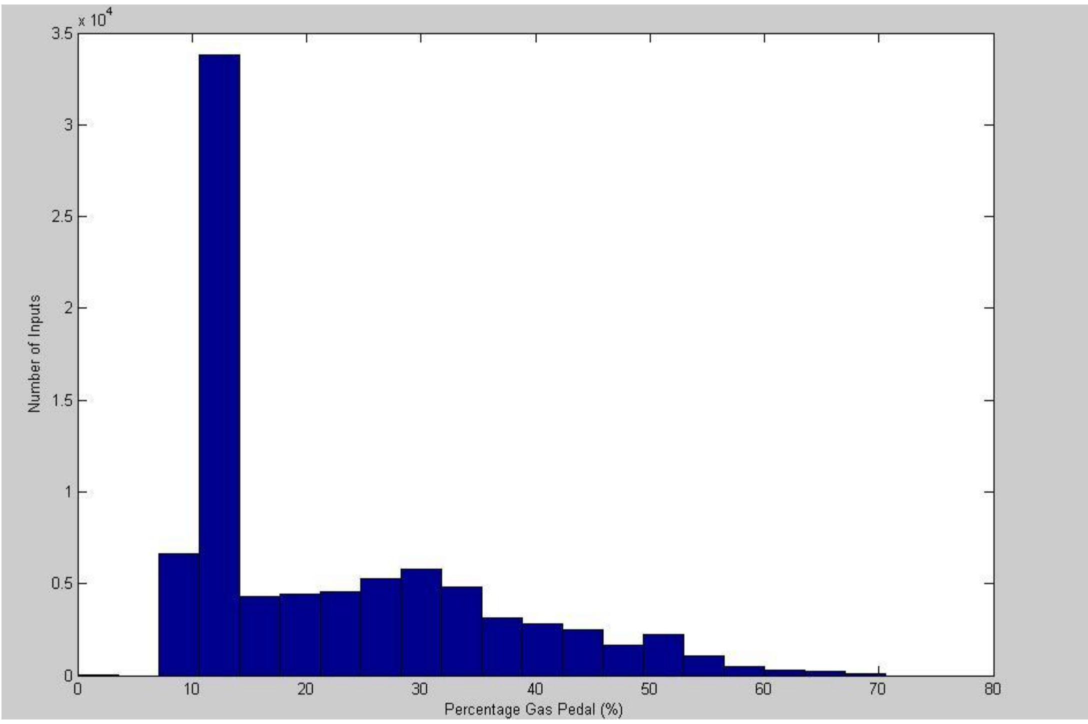


Figure 5.14: Percentage Gas Pedal Histogram of Driver F1012

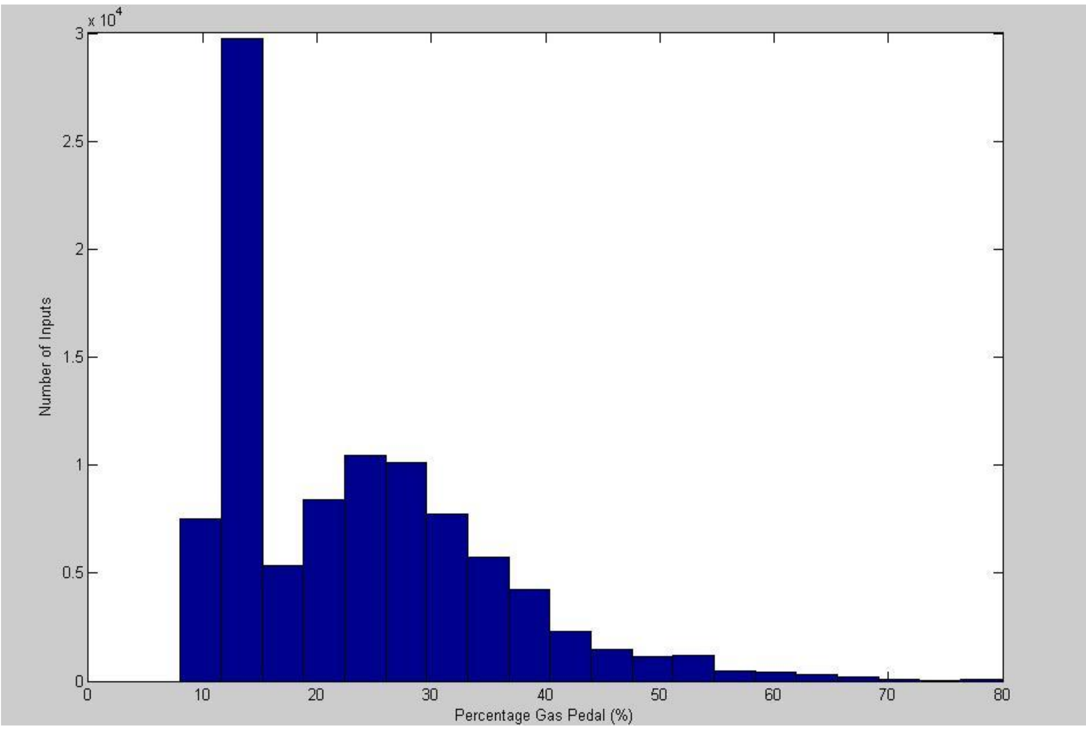


Figure 5.15: Percentage Gas Pedal Histogram of Driver F1019

These histograms in Figures 5.13-5.15 show at what percentage was the gas pedal pressed throughout the test. Istanbul traffic does not let use of full potential of cars generally and results support this, more than 30 percent of gas is merely used. Average usages of gas pedal are 21.93%, 22.35% and 23.13%. It is obvious for efficient fuel consumption, a controlled use of gas pedal is required. F1003 seems to have the least consumption however F1012's speed/gas ratio is slightly better.

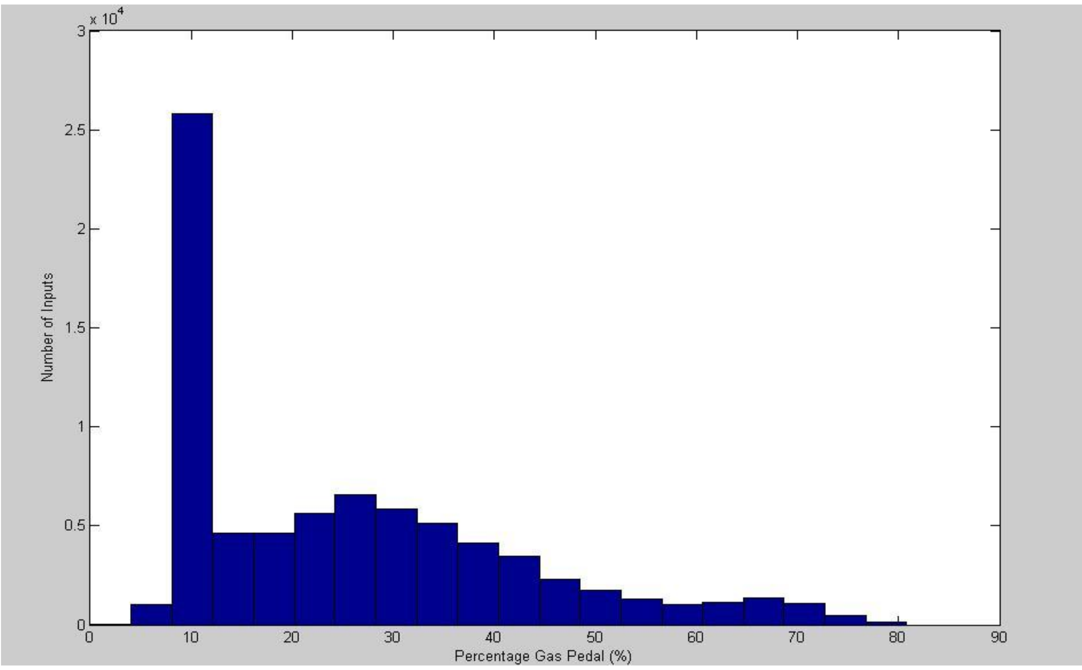


Figure 5.16: Percentage Gas Pedal Histogram of Driver M1049

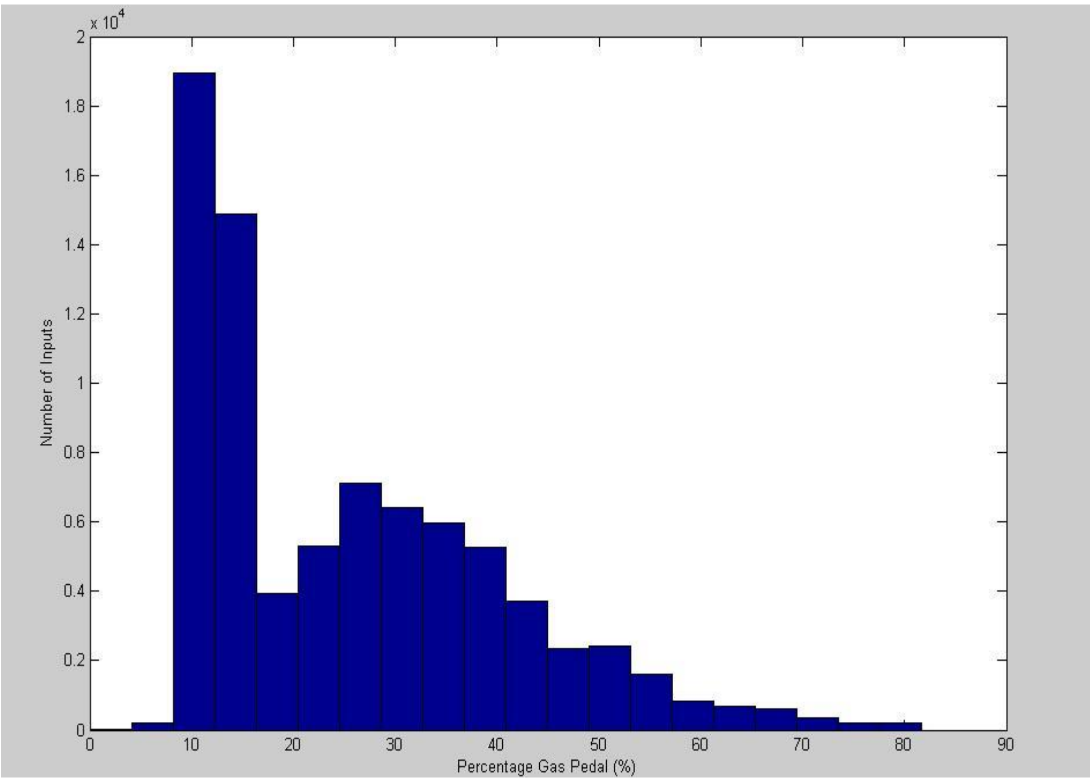


Figure 5.17: Percentage Gas Pedal Histogram of Driver M1066

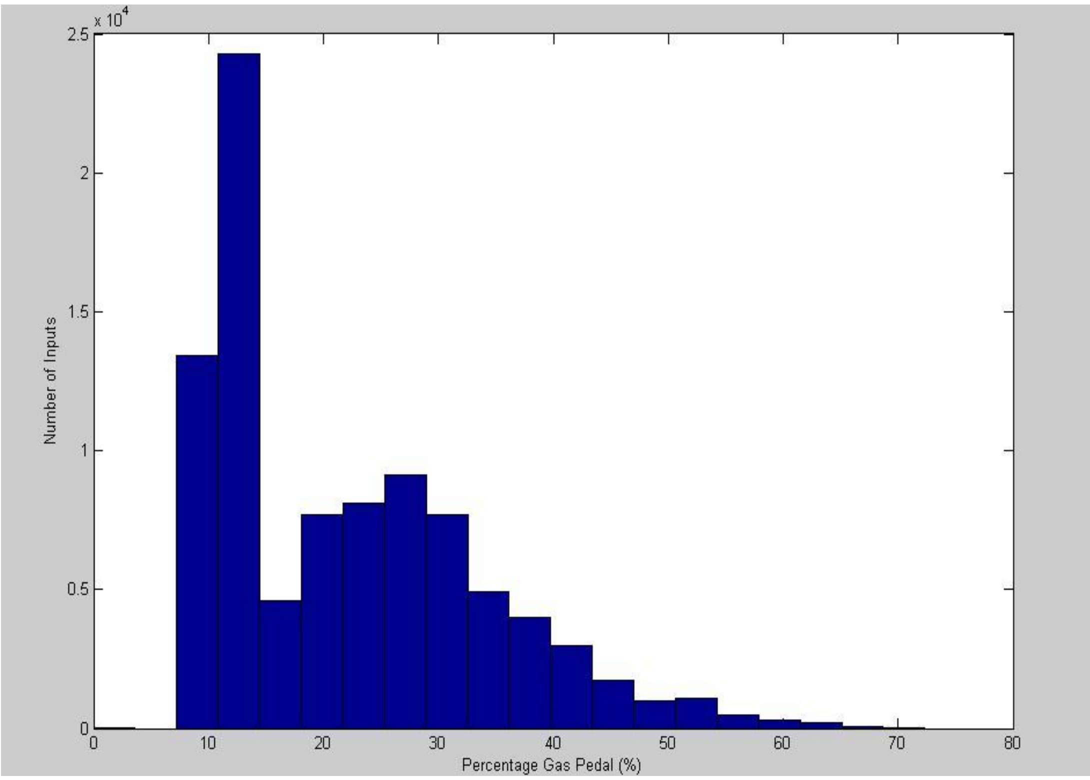


Figure 5.18: Percentage Gas Pedal Histogram of Driver M1089

Although speed and gas percentage are proportional, they are not the same thing. Male gas pedal histograms in Figures 5.16-5.18 show this fact clearly, they are 25.89%, 25.34% and 22.08%. Even the slowest driver M1089's gas percentage is

22.08% is greater than F1003's with 21.93% and close to F1012's with 22.35%. It can be stated that men tend to use gas pedal more often and yield more fuel consumption than women.

5.4 Brake Pedal:

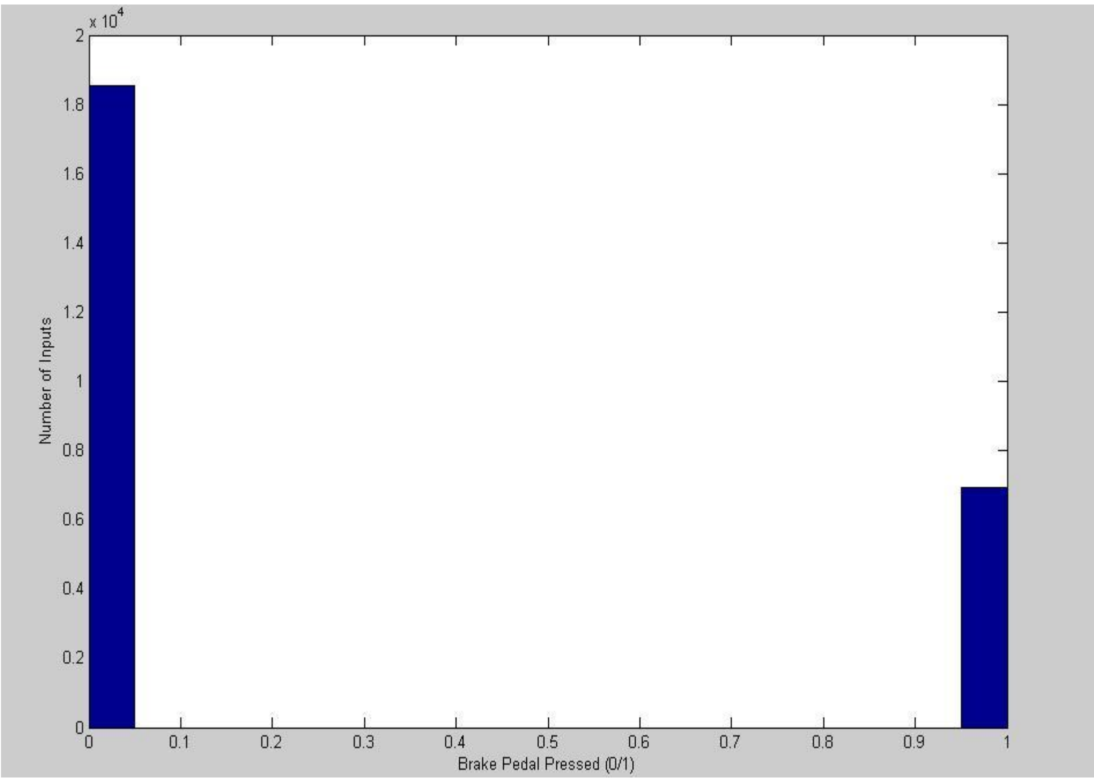


Figure 5.19: Brake Pedal Histogram of Driver F1003

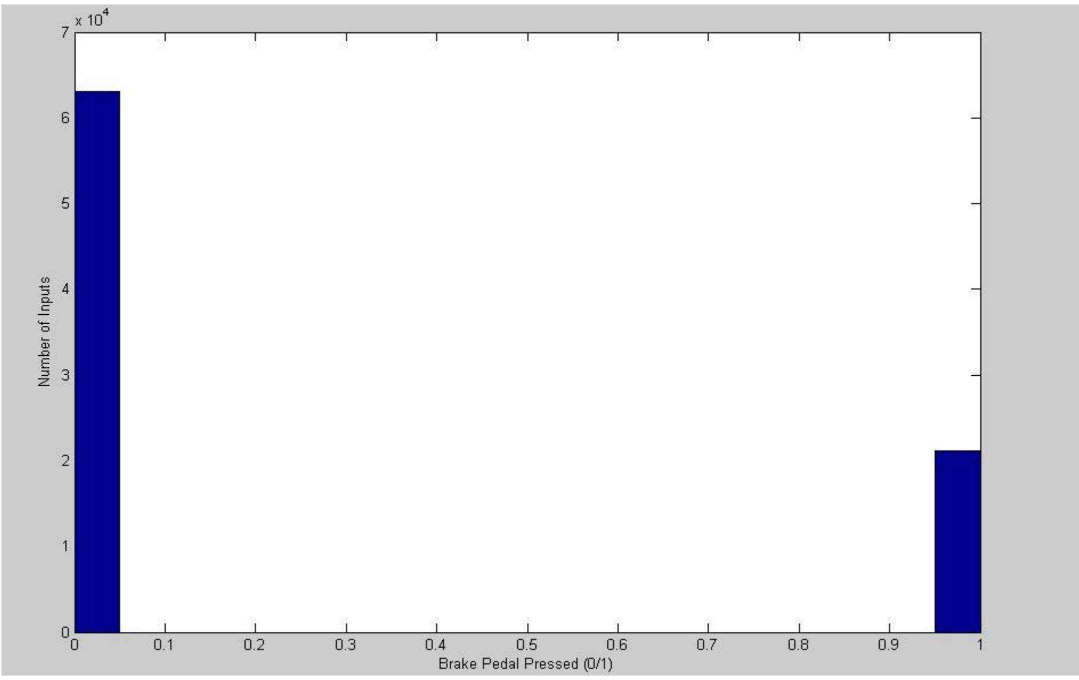


Figure 5.20: Brake Pedal Histogram of Driver F1012

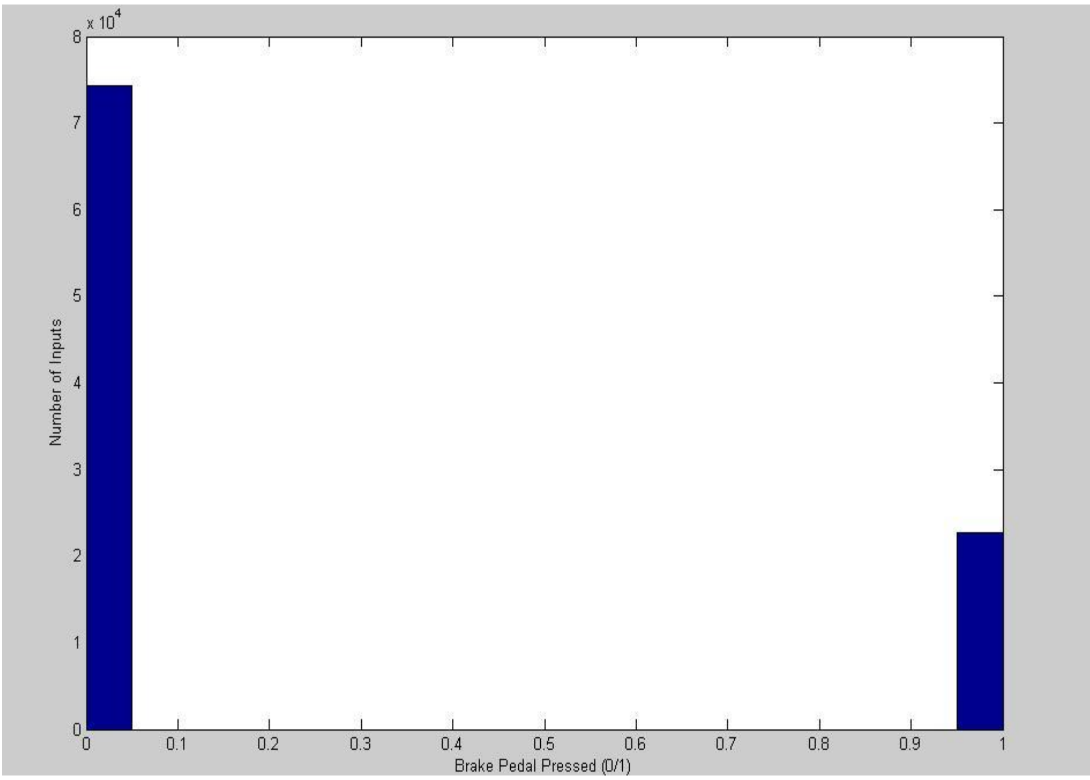


Figure 5.21: Brake Pedal Histogram of Driver F1019

Brake pedal histograms simply show whether the brake pedal is pressed or not through the data. Only solid fact that can be extracted from these histograms is the pressed/unpressed ratio of brake pedal. Among people minimal use of brake pedal is considered as a sign of expert driving, this is mostly true since amateur drivers tend to brake a lot. Additionally excess use of brake pedal causes more fuel consumption. Ratios are respectively; 0.37, 0.34 and 0.31 for female drivers as in Figures 5.19-5.21.

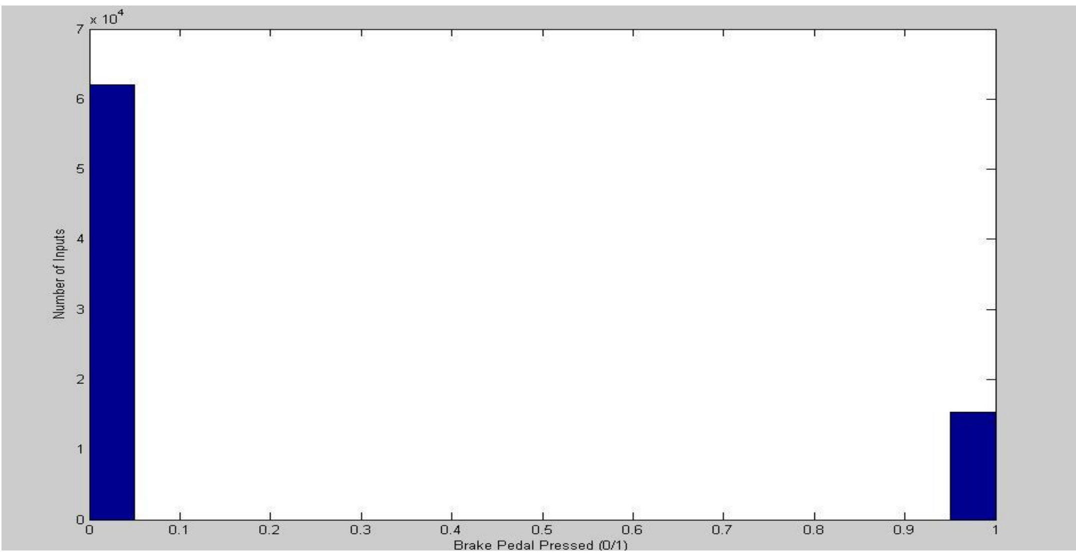


Figure 5.22: Brake Pedal Histogram of Driver M1049

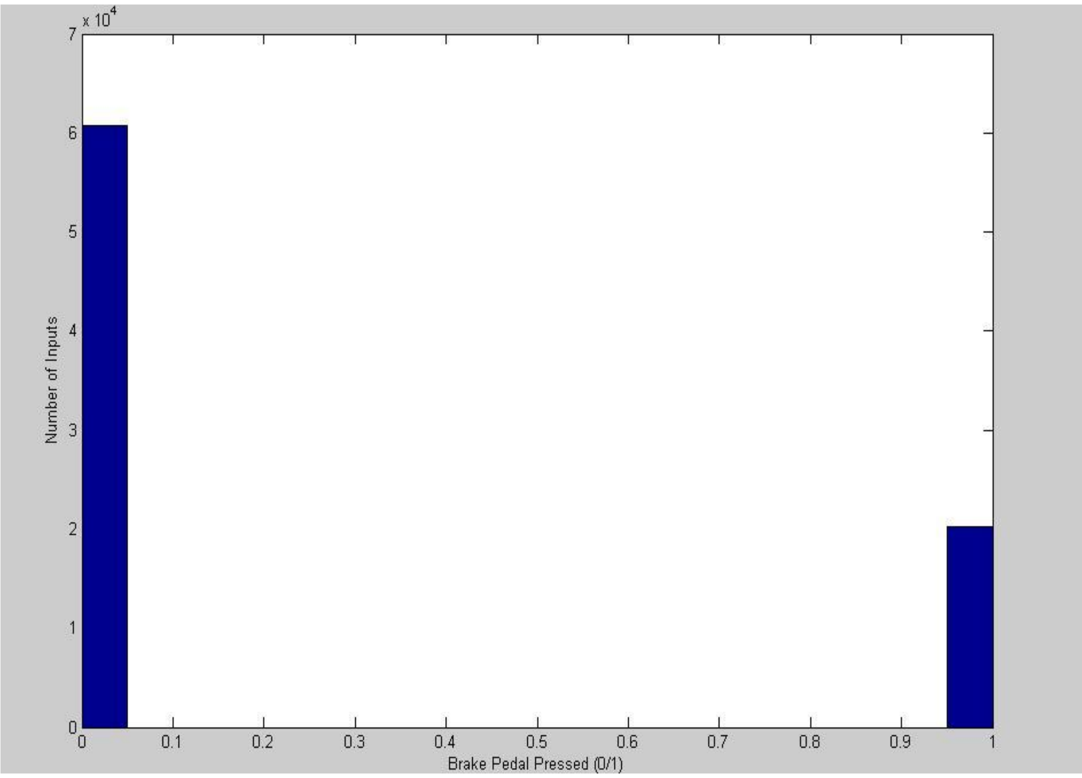


Figure 5.23: Brake Pedal Histogram of Driver M1066

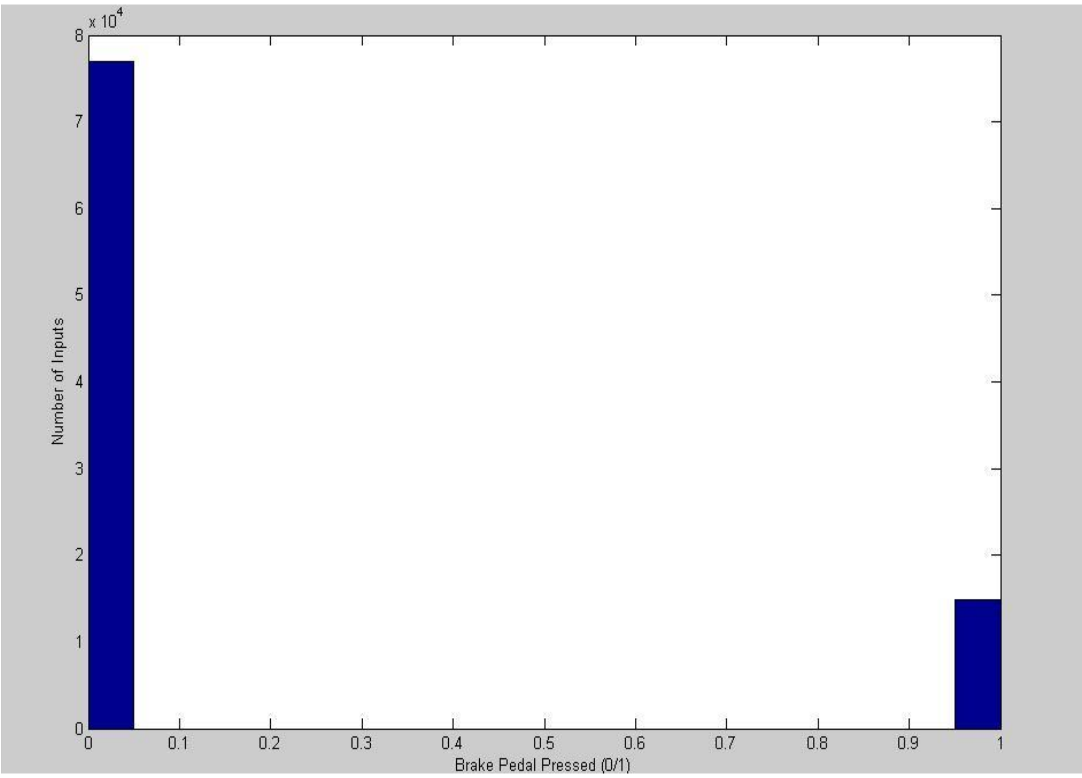


Figure 5.24: Brake Pedal Histogram of Driver M1089

Male brake pedal ratios are 0.25, 0.33 and 0.19 in Figures 5.22-5.24, which indicates men braked less than women. Of course results could be affected by traffic conditions but from the data it is understood that an extraordinary situation is not present. Even though there could be small imperfections about test route conditions, they are negligible.

6. RESULTS AND DISCUSSION:

Automobile safety is a concept that is closely related to everyone and impossible to ignore, as long as automobiles remain tightly attached to daily life. Even though people are expected to obey the rules and take certain precautions, development of this industry shows, it is not enough. What people are unable to do or does not take seriously, are expected from automobiles to be done by. This leads to smarter and safer cars for the future, hopefully with lesser traffic accidents.

This thesis is done having an insight of emphasizing automobile safety and create or innovate ideas about this field. One advantage is there is a huge source to give support and feedback as DriveSafe, so detailed explanation of DriveSafe was mandatory to include, since data used in analyses was coming from there.

First data analyses were about determining test car displacement and maneuvers during test drive. GPS data was the first type to be used for this purpose, and test route was clearly understood with it. Test route was represented with both geodetic and Cartesian formats. Geodetic format is easy for determining directions and up is always north and similarly south, east, west as down, right and left respectively. Whereas Cartesian format is more realistic with taking into account the Earth's special parameters to view it, like looking at the test route from space. Both routes looked identical and fitted format descriptions. GoogleEarth part useful for embracing test route and make connections to real environments throughout the city. Also it is seen that GPS device worked fine, since data points nearly always take their places in correct positions on GoogleEarth although manufacturer's claim of 40 centimeters of precision is slightly exaggerated. Still lane following of the car might be roughly possible over GoogleEarth.

In the next chapter alternative methods were tried to get to same point which is achieving test route. IMU sensor data was processed and modeled to give position data by integration. Results were like scrambled puzzle pieces as foreseen before. There are some factors responsible as acceleration in Z direction annihilates correct orientation of X-Y axes. Update rate is another major problem that might be considered a common problem for these kinds of devices. Also lack of a Kalman filter greatly influences the legitimacy of these results.

After struggling with IMU sensor, combinations of steering angle, speed data and the double-track model of the vehicle that was specially designed for the test car, were put on the counter. Steering angle and vehicle speed coming from CANBUS dataway of the test car enabled to draw a route according to these data. To develop the model a speed controller was added to match speeds and overcome errors. Different route plots were formed with changing controller gain and in the end one was selected that was most related to GPS route. It was better than IMU plots but not completely right as it should be. Start and operating times of different hardwares can be blamed for this reason along with the causes that were stated for IMU sensor. GPS device takes some time to boot and find satellites for example whereas CANBUS starts right away. Generally it is seen all these methods give closely related results in different scales but they can be further searched to make better. For instance, GPS hardware as an accessory in cars is the most expensive one, if it was possible to imitate GPS module's job through CANBUS or IMU, it would be very cost-friendly and could exist in every car.

Final chapter was on driver profiles rather than test car. Again specific data were taken from CANBUS like brake pedal signal, gas pedal press percentage, vehicle speed and steering angle. These might look simple, however they give characteristic information that can be used to classify drivers. Speed profile and gas percentage could determine how aggressive the car is driven or brake and steering angle give clues about experience level. These are just few data and others could be analyzed to achieve safer, fuel efficient and nature-saving drives. All these data could be stored and sent to a main data processing center to create personal driving profiles and adjust the car accordingly or if the car is advanced enough it could decide on calibrating itself.

There are much to be extracted from these data and many projects to be projected with their light. Tuning safety systems for emergency situations is incomplete; they should also be tuned specifically for their driver too. Hopefully this hard task will one day be accomplished.

REFERENCES:

[1] **Url-1** *<http://en.wikipedia.org/wiki/Automobile_safety>*, taken on 11.03.2011.

[2] **Güvenç, L., Aksun, Güvenç, B., Acarman, T., Aytekin, B., Daniş, S., Atam, E. and Dinçmen, E.,** 2007. Güvenli Sürüş (Drive Safe) Projesi İ.T.Ü Çalışma Grubu Final Raporu, pp.2.

[3] **Güvenç, L., Aksun, Güvenç, B., Acarman, T., Aytekin, B., Daniş, S., Atam, E. and Dinçmen, E.,** 2007. Güvenli Sürüş (Drive Safe) Projesi İ.T.Ü Çalışma Grubu Final Raporu, pp.6-7.

[4] **Url-2** *<http://en.wikipedia.org/wiki/Alesis_ADAT_HD24>*, taken on 28.03.2011.

[5], [6] **Url-3** *<http://www.alesis.com/hd24#>*, taken on 28.03.2011.

[7] **Güvenç, L., Aksun, Güvenç, B., Acarman, T., Aytekin, B., Daniş, S., Atam, E. and Dinçmen, E.,** 2007. Güvenli Sürüş (Drive Safe) Projesi İ.T.Ü Çalışma Grubu Final Raporu.

[8] **E. Af Wahlberg, A. and Dorn, L.,** 2009.Absence behavior as traffic crash predictor in bus drivers, *Journal of Safety Research.*

[9] **Ng Boyle, L., Tippin, J., Paul, A. and Rizzo, M.,** 2007. Driver performance in the moments surrounding a microsleep, *Transportation Research Part F 11 (2008) 126-136*.

[10] **Veeraraghavan, H., Bird, N., Atev, S. and Papanikolopoulos, N.,** 2007. Classifiers for driver activity monitoring, *Transportation Research Part C 15 (2007) 51-67*.

[11] **Han, I. and Yang, K. S.,** 2009. Characteristic Analysis for Cognition of Dangerous Driving Using Automobile Black Boxes, *International Journal of Automotive Technology, Vol.10, No.5, pp.597-605 (2009)*.

[12] **Url-4** *<http://www.geoplane.com/gps.html>*, taken on 30.03.2011.

[13] **Url-5** *<http://en.wikipedia.org/wiki/GPS_tracking_unit>*, taken on 30.03.2011.

[14] **Url-6** *<http://en.wikipedia.org/wiki/NMEA>*, taken on 30.03.2011.

[15] **Url-7** <*http://home.mira.net/~gnb/gps/nmea.html*>, taken on 31.03.2011.

[16] **Barton, C. E. and Tarlowski, C. Z.,** 1990. Geomagnetic, geocentric, and, geodetic coordinate transformations, *Computers & Geosciences Volume 17, Issue 5, 1991, pp 669-678.*

[17] **Url-8** <*http://www.earthpoint.us/ExcelToKml.aspx*>, taken on 02.04.2011.

[18] **Url-9** <*http://en.wikipedia.org/wiki/Real_Time_Kinematic*>, taken on 19.04.2011.

[19] **Url-10** <*http://en.wikipedia.org/wiki/Geodetic_system#From_ECEF_to_ENU*>, taken on 19.04.2011.

[20] **Url-11** <*http://en.wikipedia.org/wiki/File:ECEF_ENU_Longitude_Latitude*>, taken on 19.04.2011.

[21] **Rill, G.,** 2005. Vehicle Dynamics Lecture Notes, University of Applied Sciences, Fachhochschule Regensburg.

[22] **Chung, T. and Yi, K.,** 2006. Design and Evaluation of Side Slip Angle-Based Vehicle Stability Control Scheme on a Virtual Test Track, *IEEE Transactions On Control Systems Technology, Vol.14, No.2, March 2006, pp.225*.

[23] **Chung, T. and Yi, K.,** 2006. Design and Evaluation of Side Slip Angle-Based Vehicle Stability Control Scheme on a Virtual Test Track, *IEEE Transactions On Control Systems Technology, Vol.14, No.2, March 2006, pp.225-226*.

[24] **Aksun, Güvenç B., Güvenç, L., Dinçmen, E., Altuğ, E., Aytekin, B., Daniş, S., Acarman, T., Sezer, V., Ararat, Ö. and Öncü, S.,** 2010. Framework for Development of Driver Adaptive Warning and Assistance Systems that will be Triggered by a Driver Inattention Monitor, *International Journal of Vehicle Design, Vol.52, No.1/2/3/4, pp.20-37, 2010.*

[25] **MATLAB R2008a Help File, search results on Histograms.**

APPENDIX:

APPENDIX A: Additional details concerning GPS chapter.

APPENDIX B: MATLAB files.

APPENDIX A:

A.1 GPS Data Points:

Table A.1: GPS Data Points Gathered For Each Driver

Driver ID	Data Points	Driver ID	Data Points	Driver ID	Data Points
IF 1003	1261	IM 1020	2651	IM 1055	4842
IF 1004	1093	IM 1021	4272	IM 1056	3634
IF 1005	N/A	IM 1022	3706	IM 1057	3640
IF 1006	4799	IM 1023	5040	IM 1058	4086
IF 1007	N/A	IM 1024	5981	IM 1059	5213
IF 1008	N/A	IM 1025	3945	IM 1060	4578
IF 1009	6012	IM 1026	3324	IM 1061	4519
IF 1010	N/A	IM 1027	4383	IM 1062	4234
IF 1011	3921	IM 1028	3540	IM 1063	3909
IF 1012	3975	IM 1029	3751	IM 1064	3671
IF 1013	3985	IM 1030	3580	IM 1065	3793
IF 1014	4260	IM 1031	5075	IM 1066	4153
IF 1015	6037	IM 1032	4742	IM 1067	3362
IF 1016	N/A	IM 1033	4173	IM 1068	4925
IF 1017	4277	IM 1034	6153	IM 1069	4243
IF 1018	4900	IM 1035	7765	IM 1070	4266
IF 1019	4974	IM 1036	4162	IM 1071	3836
IM 1001	N/A	IM 1037	3804	IM 1072	4208
IM 1002	N/A	IM 1038	3994	IM 1073	6302
IM 1003	N/A	IM 1039	5121	IM 1074	4590
IM 1004	N/A	IM 1040	4704	IM 1075	6117
IM 1005	1385	IM 1041	4311	IM 1076	3653
IM 1006	1178	IM 1042	2413	IM 1077	4722
IM 1007	1519	IM 1043	4107	IM 1078	4503
IM 1008	1155	IM 1044	4291	IM 1079	4719
IM 1009	6012	IM 1045	4616	IM 1080	4504
IM 1010	1415	IM 1046	4516	IM 1081	3934
IM 1011	944	IM 1047	3907	IM 1082	3368
IM 1012	N/A	IM 1048	4374	IM 1083	4171
IM 1013	N/A	IM 1049	3485	IM 1084	3787
IM 1014	N/A	IM 1050	4149	IM 1085	4637
IM 1015	N/A	IM 1051	3697	IM 1086	3727
IM 1017	N/A	IM 1052	3857	IM 1087	3589
IM 1018	4030	IM 1053	4797	IM 1088	4173
IM 1019	3529	IM 1054	6182	IM 1089	4227

A.2 GPS Sentence Codes and Descriptions for NMEA Format:

- $GPAAM - Waypoint Arrival Alarm
- $GPALM - GPS Almanac Data
- $GPAPA - Autopilot format "A"
- $GPAPB - Autopilot format "B"
- $GPASD - Autopilot System Data
- $GPBEC - Bearing & Distance to Waypoint, Dead Reckoning
- $GPBOD - Bearing, Origin to Destination
- $GPBWC - Bearing & Distance to Waypoint, Great Circle
- $GPBWR - Bearing & Distance to Waypoint, Rhumb Line
- $GPBWW - Bearing, Waypoint to Waypoint
- $GPDBT - Depth Below Transducer
- $GPDCN - Decca Position
- $GPDPT - Depth
- $GPFSI - Frequency Set Information
- $GPGGA - Global Positioning System Fix Data
- $GPGLC - Geographic Position, Loran-C
- $GPGLL - Geographic Position, Latitude/Longitude
- $GPGRS - GPS Range Residuals
- $GPGSA - GPS DOP and Active Satellites
- $GPGST - GPS Pseudorange Noise Statistics
- $GPGSV - GPS Satellites in View
- $GPGXA - TRANSIT Position
- $GPHDG - Heading, Deviation & Variation
- $GPHDT - Heading, True
- $GPHSC - Heading Steering Command
- $GPLCD - Loran-C Signal Data
- $GPMSK - Control for a Beacon Receiver
- $GPMSS - Beacon Receiver Status
- $GPMTA - Air Temperature (to be phased out)
- $GPMTW - Water Temperature
- $GPMWD - Wind Direction

- $GPMWV - Wind Speed and Angle
- $GPOLN - Omega Lane Numbers
- $GPOSD - Own Ship Data
- $GPR00 - Waypoint active route (not standard)
- $GPRMA - Recommended Minimum Specific Loran-C Data
- $GPRMB - Recommended Minimum Navigation Information
- $GPRMC - Recommended Minimum Specific GPS/TRANSIT Data
- $GPROT - Rate of Turn
- $GPRPM - Revolutions
- $GPRSA - Rudder Sensor Angle
- $GPRSD - RADAR System Data
- $GPRTE - Routes
- $GPSFI - Scanning Frequency Information
- $GPSTN - Multiple Data ID
- $GPTRF - Transit Fix Data
- $GPTTM - Tracked Target Message
- $GPVBW - Dual Ground/Water Speed
- $GPVDR - Set and Drift
- $GPVHW - Water Speed and Heading
- $GPVLW - Distance Traveled through the Water
- $GPVPW - Speed, Measured Parallel to Wind
- $GPVTG - Track Made Good and Ground Speed
- $GPWCV - Waypoint Closure Velocity
- $GPWNC - Distance, Waypoint to Waypoint
- $GPWPL - Waypoint Location
- $GPXDR - Transducer Measurements
- $GPXTE - Cross-Track Error, Measured
- $GPXTR - Cross-Track Error, Dead Reckoning
- $GPZDA - UTC Date / Time and Local Time Zone Offset
- $GPZFO - UTC & Time from Origin Waypoint
- $GPZTG - UTC & Time to Destination Waypoint

APPENDIX B:

B.1 M-File Function to Convert from Geodetic to Cartesian:

```
a = 6378137;          % Semi-Major Axis (re)
f = 1/298.25722563;          % Reciprocal of Flattening
e = (2*f)-(f^2);          % First Eccentricity Squared (ε2)

lat = data(1:4227,1)*(pi/180);          % Latitude
long = data(1:4227,2)*(pi/180);          % Longitude

h = data(1:4227,3);          % Height Above Geoid (Altitude)
v = a*diag(inv(diag([sqrt(1-e*diag(sin(lat)*sin(lat)'))])));

X = diag((v+h)*(diag(cos(lat)*cos(long)'))');          % X Coordinate
Y = diag((v+h)*(diag(cos(lat)*sin(long)'))');          % Y Coordinate
Z = diag(((1-e)*v+h)*sin(lat)');          % Z Coordinate
```

B.2 M-Files Needed to Simulate Vehicle Model:

Parametermegane.m:

```
lf=1.01; % Distance From Center of Gravity to Front Axle
lr=1.45; % Distance From Center of Gravity to Rear Axle
l=lf+lr; % Distance Between Front and Rear Axles
Ts=0.8;   % Distance Between Left and Right Suspensions
R=0.3; % Wheel Radius
fR=0.015; % Roll Drag Coefficient
d=fR*R; % Point of Touch of Wheel Load Distortion From Axis
Iw=0.9; % Moment of Inertia of the Wheel
m=1590; % Total Mass
ms=1410;% Pendent Mass
mu=m-ms;% Non-Pendent Mass
e=0.26;% Distance Between Center of Gravity of Pendent Mass and Roll Axis
g=9.81;% Gravity
Iz=2910; % Moment of Inertia Around Z Axis
Izs=2810;% Moment of Inertia of Pendent Mass Around Z Axis
Ix=700;% Total Roll Moment of Inertia
Ixs=606;% Roll Moment of Inertia of Pendent Mass
Iy=2800;% Total Pitch Moment of Inertia
Iys=2741;% Pitch Moment of Inertia of Pendent Mass
Kf=30000;% Spring Constant of Front Axles
Cf=2206;% Damping Coefficient of Front Suspensions
Kr=20000;% Spring constant of rear axles
Cr=2206;% Damping Coefficient of Rear Suspensions
V=0.1;% Initial Speed
w0=V/R;% Initial Angular Speeds of Wheels
Sr=17;% Steering Gear Ratio
Cd=0.4;% Aerodynamic Drag Coefficient
Af=1.8;% Frontal Area of the Vehicle
roa=1.2257;% Air Density
```

```
lwf=1.54;% Front Axle Track Width
lwr=1.53;% Rear Axle Track Width
Kantirollf=22000;% Front Antiroll Bar Stiffness
Kantirollr=19710;% Rear Antiroll Bar Stiffness
muf=100;% Mass of Front Axle
mu_fr=muf/2;% Front Right Non-pendent Mass
mu_fl=muf/2;% Front Left Non-pendent Mass
mur=80;% Mass of Rear Axle
mu_rr=mur/2;% Rear Right Non-pendent Mass
mu_rl=mur/2;% Rear Left Non-pendent Mass
pf=0.277;% Height of Front Roll Center
pr=0.286;% Height of Rear Roll Center
hf=0.277;% Height of Center of Gravity of Front Axle
hr=0.286;% Height of Center of Gravity of Rear Axle
kt=220000;% Spring Constant of Wheel
```

BIOGRAPHY

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